Resilient Design: An Ecological Approach to Coastal Flooding Mitigation

An Honors Thesis LA 404

By

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Ball State University
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May 2012

Expected Date of Graduation

May 2012

ABSTRACT

Since the 19th century, the likes of Thoreau, Olmsted, and Muir have been warning about the inevitable ramifications of human abuse of landscapes. Although we have come a long way since then, today's threats of climate change hazards combined with the continuous negative anthropogenic actions towards the natural landscape systems have created a dire need for change in the way we relate to the landscape.

The purpose of this project is to explore themes relating to how intense static human development can work with rather than against dynamic natural systems while still providing a high quality of life. This project looks specifically at resilient design and mitigation relating to flooding of coastal areas in the United States. The concentration and number of people and structures has increased along the nation's coasts due to high value property and aesthetic significance. However, this type of development and dense concentration leads to environmental degradation of natural systems and puts a high demand on the carrying capacity of the fragile coastal areas. This proposal encourages designers to look at different methods to approach development in these vulnerable areas while still allowing natural systems to work as nature wants.

This will be accomplished through the design of an ecologically based landscape plan in a densely populated urban park for the city of Miami, Florida. Ecological based designs will be implemented to increase the quality of water on site, habitat for marine and wildlife around the site, and serve as an example of how ecological designs can still relate to urban areas. Extensive review of available research, case studies like that of the Toronto Riverfront, and analysis will conclude in a master plan of resilient design to mitigate the threat of flooding on site while increasing quality of life for users as well as the natural environment.

ACKNOWLEDGEMENTS

I would like to give a big thank you to my family. They have been fully supportive of my passion for landscape architecture and sustainable design and have been behind me emotionally and financially my entire career. It has been a quick five years of school, but I couldn't have accomplished any of this without the strength and confidence they give me on a daily basis.

In regards to my professional development, I want to thank my friends and studio mates that have pushed me to become a better designer with every pen stroke, layout, and project that comes our way. We have supported each other in the good and bad, and I couldn't imagine going through any of this without them.

This project, which culminated a year long process, was a direct result of the help of many people. I would first like to thank my mentor, Simon Bussiere. I also want to thank my studio professors John Motloch, Carla Corbin, and Martha Hunt. This project combined knowledge that I have gained throughout my years at Ball State University and every professor and mentor I have encountered deserves thanks for their time and passion spent to teach in order to further the field of landscape architecture.

CONTENTS

INTRODUCTION

Environmental perils such as floods do not exist independently of society because they are defined, reshaped, & redirected by human actions. The challenges extreme weather events present impose stresses and new demands on the design of buildings, communities and the natural land and water resources. These stresses are provoked by climate change but also by the way development has intensely taken over vulnerable ecosystems in the last few decades. The Intergovernmental Panel on Climate Change, the leading international body for the assessment of climate change, summarizes impacts of climate change on the world's water resources in their 2007 report on *Climate Change and Water*. One example from this report includes increased precipitation intensity and variability which will increase risk of rain-generated flooding. Another example is that sea level is projected to extend to areas of salinization in groundwater and estuaries, resulting in a decrease of freshwater availability for humans and ecosystems in coastal areas. In his book, Logic, the Nature of Inquiry, John Dewey states that "environmental problems stimulate inquiry and action, which transform the environment, engendering further problems, inquiries, actions, and consequences in a potentially endless chain." This statement directs the outline for the research in the rest of this proposal.

Heavy development along the coast of Miami, Florida, has damaged coastal marshes, wetlands, and mangroves that historically provided important buffers to coastal storms and storm surges. Floods, as the nation's most frequent and injurious natural hazard, stem from predicted results of interactions among three major systems: influences exerted by the physical environment, how human systems created and redistribute hazards, and hazards that result from the nature of the constructed environment (Mileti). The ability of the built environment to withstand impacts of natural forces plays a direct role in determining injuries and loss in a community.

Fortunately, the design and enhancement of the water balance and resources of natural watersheds, floodplains, and built infrastructure can mitigate and help prevent severe weather and climate change. Sustainable hazards mitigation can result in disaster-resilient communities that help to adapt to natural hazards as well as reduce resulting deaths, injuries, costs, and social, environmental, and economic disruption. The purpose of resilient design is to reestablish the functioning of relationships, and interrelationships within a living landscape. Ecological planning presents an idea of regenerative design which, "focuses on renewing resources of landscape to ensure that the essential ecological processes continue" (Ndubisi). It is based on the idea that the landscape provides ongoing fiber, energy, and materials for daily physical and economic activities.

With the increase in natural hazards over the past few decades being paralleled to anthropogenic actions, a change in "built *versus* natural" to "built *with* natural" needs to occur. This proposal seeks to understand all the forces that bring about the need for intervention and to propose appropriate spatial structures and designs to mitigate the forces and prevent them from occurring again. On the following pages you will find what is causing an increase in flooding, what corrective measures may be needed to mitigate the significant damages, and how resilient design can relate to an urban context outlined in the project background, problem statement, methodology, as well as attached appendices.

REVIEW OF RELATED LITERATURE

Introduction

Resilient design encompasses several disciplines as well as several elements to successfully plan and mitigate for severe weather events. The following literature review addresses four key points in examining how to implement resilient designs into urban areas. The first is an understanding of *Factors that Cause Flooding in Coastal Areas*. A complete understanding of the different factors that add to the threat of flooding is vital in being prepared to plan and design for the mitigation of it. Along with literature about different factors, concerns linked with these factors will be addressed as well. The second area is *How Resilient Design Can Mitigate* these factors. The implementation of different ecological designs offers opportunities to rethink how to design coastal areas to support rather than harm the natural ecosystems. The third area of the literature review addresses *Miami's Context* and looks at the history of the site and how the built environment has encroached upon and hindered the natural systems. This area will set the context for the project. The final areas of review include literature on *Climate Change Projections* and how these projections will impact Miami specifically.

Contributing Factors to Coastal Flooding

A good understanding of several factors that instigate flooding will be able to plan for these situations. For the development of a socially-responsible and ecologically-sound landscape, a comprehension of the perceptions, values, and meanings associated with the landscape is needed. The paradox of flooding is that it is essential to a healthy environment while at the same time is potentially a hazard to developed areas as well as to human activities in the floodplain. Increased flooding can be ascribed to a combination of two factors: changes in land use and increased precipitation as a consequence from global climate change.

One major contributor to increased precipitation has been climate change. In an interview in 2010 with Kristina Hill, PhD, Affiliate ASLA and Chair of Landscape Architecture Department at the University of Virginia by the American Society of Landscape Architects, Hill states the main problem we are facing with global climate change is the increase in climate extremes—from snowfall and melt to heat and from floods to drought. The 2007 *Global Climate Change* report states that one of the clearest precipitation trends in the United States is the increasing frequency and intensity of heavy downpours (IPCC 2007). *Confronting Climate Change: An Early Analysis of Water and Wastewater Adaption Costs* was released by the National Association of Metropolitan Water Agencies in 2009. In this report, impacts common to all areas are predicted to range from an increase of extreme precipitation events to impacts on ecology, agriculture and stormwater. Specifically for the Southeast, the report anticipates greater uncertainty in the water supply coupled with increased demand for maintaining quality and quantity of discharges to rivers and streams for environmental purposes. There is no disagreement among these three sources about the threat of climate change; the only differences are when and to what scale we will experience the threats.

Sea level rise is another acknowledged result of global warming. In Design for Flooding, Donald Watson and Michele Adams state that even small increases in sea level rise will create risks for natural systems. With just a few inches of rise, ocean salinity will be driven inland and will seep into freshwater aquifers. Also, existing built infrastructure, including urban stomwater and sewer outfalls, will be impacted by any elevation of sea level rise. More unpredictable threats associated with sea level rise have to do with weather patterns being intensified due to atmospheric pressure. Mileti claims that "climate change models point with high confidence to an increase in floods as a result of a trend toward more convective precipitation due to the warmer atmosphere and greater atmospheric absolute humidity. Rising sea levels will likely worsen the impact of storm surges as well." However, it is not climate change that creates the threat of flooding: it is when climate change is combined with the present abuse of natural landscapes in the built environment.

In his book Design for Disaster, Mileti attributes the increase of losses from disaster to not only climate change but also to increased population and growing density of built environment. Intensive development in hazardous areas has dramatically increased exposure to damages from disasters, including flooding. Watson and Adams agree and go on to say that climate, weather, and flooding are influenced by the way that communities and urban infrastructure are designed and built. They go on to explain that fifty percent of the U.S. population resides in coastal counties and waterways due to high property values as well as social values. As population increases along these waterways, the built environment is expanding more and more into vulnerable areas.

Economic development in concert with increasing population is the other huge factor that has added pressure on the alteration of the flow of surface water systems and the landscape floodplains according to the publication Canada Water Book on Flooding. Canada has witnessed an elimination of wetlands, increased shoreline erosion, and a loss of the sediment filtration capacity in the floodplains due to human efforts to constrict the active zone of flood plains in order to build in sensitive areas. These are common consequences from construction of dykes and diversion channels, channel dredging and alignment, and drainage of wetlands along coast lines. Other outcomes include decline of fish and wildlife habitats, and the disruption of entire ecosystems. Watson and Adams describe the effect that intense development has on soil and its ability to retain water, which affects stormwater run-off and can attribute more to flooding. In an interview conducted by National Public Radio, Timothy Kusky, Director of the Center for Environmental Sciences at St. Louis University, spoke about the rise in floods along the Mississippi and Missouri Rivers due to increased development in the flood plains. Kusky describes how the Mississippi River was at one time 4,000 feet across at a certain point adjacent to the city of St. Louis and due to increased urban development, the same point is now only 1,000 feet across. "Common sense tells us that if we narrow the channel of water, the only place for it to go is up along the flood plain," says Kusky. Risks of flooding range from the moving of people to new areas and damaging static and dynamic systems to adversely influencing water quality and risking the health of everyone in the surrounding area. Another major risk is the mass migration of animal and plant species. Anticipating the risks will help to drive what to plan for when designing a solution.

From the resources above, it can be determined that climate pattern extremes due to climate change, increased urban development, and increased population have had a large affect on flooding of floodplain cities. The risks associated with flooding are intense and require a plan for action. In order to protect communities and the natural ecosystem from flood damage, a design of resiliency must be implemented.

RESILIENT DESIGN AND HOW IT CAN MITIGATE FLOOD DAMAGE

Watson and Adam describe resilient design as "preparing for extreme storms and flooding of inland watersheds and coastal areas to provide resiliency and emergency preparedness for natural disaster. The concept of resiliency applies lessons from natural systems to design for extreme conditions using strategies of ecological design and approaches. Resilient design presents a new paradigm for design and building professionals to create buildings, communities and regions that restore and improve our water resources and that mitigate threats of extreme weather and climate change."

During his keynote address, past ASLA president Perry Howard addressed a shift in landscape architecture towards disaster response planning and their role in rebuilding rather than recovery phase. He suggested that in disaster response planning, a designer must look at issues that affect most Americans, issues that landscape architects are most likely to affect, and which issues are of particular importance to landscape architects. He stated that landscape architects need to make a shift toward the concept of visionary planning as opposed to reactionary planning in order to eliminate or minimize effects of potential natural disasters while maintaining and enhancing a quality of life that their communities have been accustomed to.

In an article titled *Flexible Landscapes & Ecosystem Services* from the International Foundation of Landscape Architects, it was determined that, "urban space including landscapes need to become more flexible and adaptable and offer important ecosystem services for the city while respecting the socio-cultural economic implications of this transformation." Kristina Hill, PhD, Affiliate ASLA and Chair of Landscape Architecture Department at the University of Virginia, agrees with a shift and goes on to describe a more regional approach. Hill refers to what landscape ecologists call the "the matrix" which include all developed areas outside of preserved landscapes. If each developed parcel within a matrix manages the quality and quantity of stormwater runoff, for example, it contributes to a healthier landscape with sustained regional biodiversity. While designing for the environment and wildlife, one must plan for supporting species in and around urban areas by providing both a core habitat area and temporary zones available in different seasons, or perhaps different years as shifts occur in the urban mosaic.

In recent years there has been a shift from static landscapes to more ecological-based landscape design and planning lead by landscape architects such as Ian McHarg and John Muir. In his book Ecological Planning, Forster Ndubisi encourages understanding the inner workings of the landscape by looking at it in terms of structure, processes, and location. Ndubisi also recognizes the importance of protecting properties that affect several others. He points out that infrastructure systems include the point-of-beginning that trickle down in layers to the point-of-use. For instance, headwaters and tributaries drain into reservoirs. If developed areas around the headwaters were managed, then clean water would drain into the reservoir instead of unhealthy water. In Design for Flooding, authors Watson and Adams address the challenge and charge of resilient design through three realizable steps: reduction of risk by mitigation and adaptation, restoration of ecosystem services, and revitalization and reinvestment toward community and regional sustainability.

An ecological approach is arguably the best approach to mitigation in terms of preventing flood damage in community design. Mileti outlines several principles of sustainable hazards mitigation: maintain and enhance environmental quality, maintain and enhance people's quality of life, foster local resiliency to and responsibility for disasters, recognize that sustainable, vital local economies are essential, and identify and ensure inter- and intragenerational equity. Likewise, Watson and Adams go on to describe how if planned for, mitigation can serve as a huge opportunity for community well-being. If anticipated, rain collection from other intermittent and storm flooding serves to replenish and stabilize the vegetative soil layer, and cleanses areas susceptible to salinity. The plentiful rain moving across the landscape refreshes inland waterways for wildlife habitat and for countless human purposes.

Designing for resiliency is not a new concept, so there are plenty of great urban examples both nationally and abroad. There are several ways to approach resilient design depending on the site context. In an interview in 2010 with Kristina Hill, PhD, Affiliate ASLA and Chair of Landscape Architecture Department at the University of Virginia by the American Society of Landscape Architects, Hill proposes a three category action plan applied to the best approach for mitigating and adapting to climate change: to protect, renew and re-tool. She gives examples of several cities that "protect" their valuable areas through adaptive actions.

In another ecological approach Watson and Adam lay out plenty of suggestions and roles for vegetation and soil that are best practices for mitigation in their book Design for Flooding. The likes of Watson, Adam, Hill and Ndubisi prefer a natural over an altered landscape for the best mitigation practices. However, when dealing with an urban environment, this is not always possible, so they suggest using the most natural systems approach possible. Watson and Adam go on to describe why such structures and detention do not work to prevent flooding and flood damage.

Looking specifically at other vulnerable areas and how they approached mitigation would serve best for this solution. However, from the above sources, it is recommended that a natural systems approach to mitigation is best for the natural environment and therefore the surrounding communities

From the resources above, it is clear that the best approach to flood mitigation is preparation and resilient design. Although the best approaches will depend on site specific details, an ecological approach that combines several disciplines will best serve the natural ecosystem and surrounding communities.

SITE CONTEXT

Mileti states that coastal areas are the most at-risk for natural disasters and therefore should be the first priority for resilient design. Half of the U.S. population resides along waterways and coast lines (Mileti). In an executive summary of the *Ranking of the World's Cities Most Exposed to Coastal Flooding Today and In the Future* by the University of Southampton and Risk Management Solutions, Inc., Miami was ranked as the number one city in the United States in both terms of assets and population exposed to coastal flooding. This summary took into account the effects of future climate change tied with socioeconomic change. Internationally, Miami was still ranked first in terms of assets exposed, but was ninth in terms of population exposed to coastal flooding. A report titled *Social Vulnerability and Climate Change to the US Southeast* from Oxfam America in 2009 labeled Miami-Dade County as high risk in several categories including exposure to hurricane force winds (Figure1.1), flooding (Figure1.2), sea-level rise (Figure1.3), and vulnerability to multiple hazards (Figure1.4).

From the above resources, Miami was chosen as the site context due to its high density along a vulnerable site.

For an implementation to make a true impact, it will need to be looked at on several scales: regional, city, and specific site scale. Although the framework will influence the entire area of Miami-Dade County, a core project area needed to be emphasized in order to get to a more specific design level. The specific site was chosen due to it being the convergence of a wide variety of natural and man-made elements. Figure2 and Figure3 show the elements that controlled the selection of a specific site within the city of Miami.

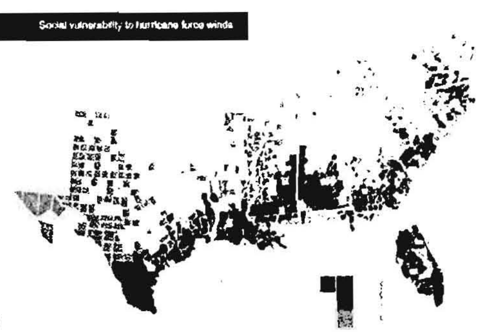


Figure1.1

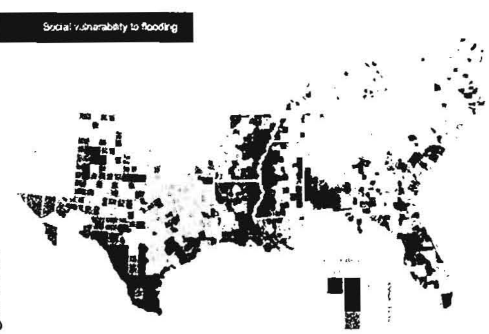


Figure1.2

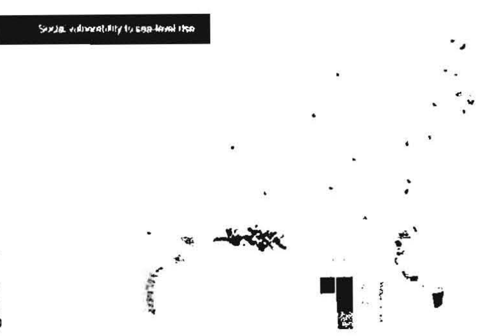


Figure1.3

Figure1.4

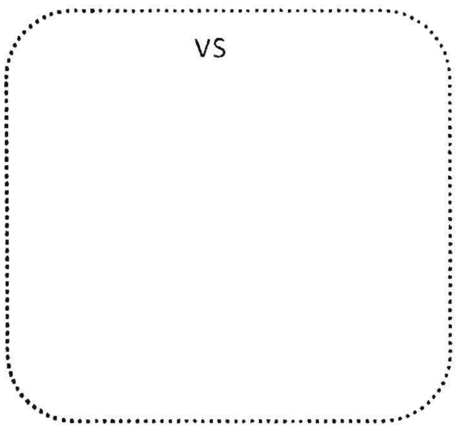


Figure2

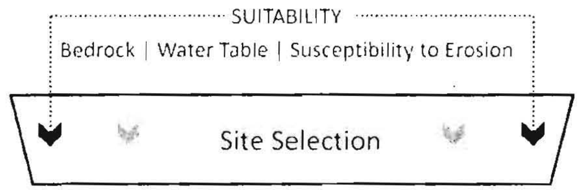


Figure3

Although there are several viable sites throughout Miami, only one has all attributes that will have full impact from the implementation of a resistant design. Figure4.1-Figure4.4 depict four sites throughout Miami with the minimum site requirements of open space available for manipulation along the coast in Miami. Figure4.1 is an existing park used by several different neighborhoods south of downtown Miami. Although this site has several elements of the site selection program, it is surrounded by mostly residential areas. The site may be used by surrounding residents, but will not impact that many people from the rest of the city. Figure4.2 is green space areas created by private homes located next to a hospital south of downtown Miami. This site will not impact as many people and also is lacking on several aspects that required for site selection. Figure4.3 is another existing park in the middle of a residential neighborhood north of downtown Miami. There is no commerce surrounding this site and it will impact few people throughout the city. Figure4.4 is the existing Bicentennial Park just north of downtown and the future home to the Miami Science Museum and Miami Art Museum. This site offers a wide variety of all the elements required through the site selection program. There is open space available for manipulation next to areas used for tourism and commerce. There are several varieties of residential types as well as economic classes next to different types of commerce and businesses. The site is located close to downtown and Miami Beach with existing public transportation routes and potential for more. Because Bicentennial Park has all the elements of the site selection program with potential for growth and manipulation, it is the best site in Miami for the implementation of the resilient design.

CLIMATE CHANGE PROJECTIONS

Most of Miami's shoreline has been rapidly developed as residential, recreational and tourism sites over the last 40 years. Other areas have long been critically important industrial locations and

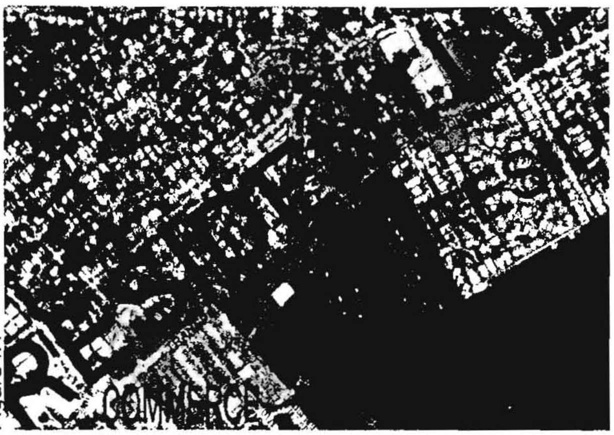


Figure4.1

Figure4.2

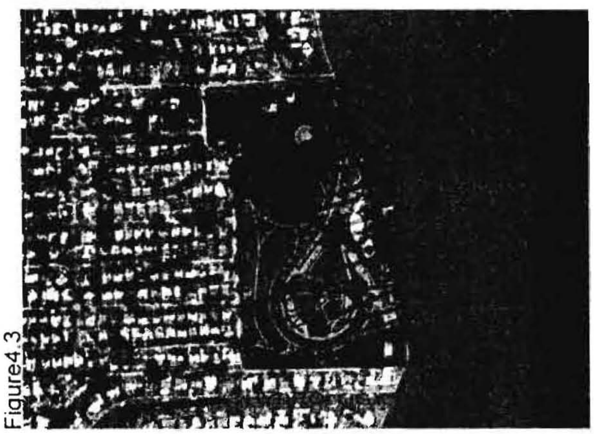


Figure4.3

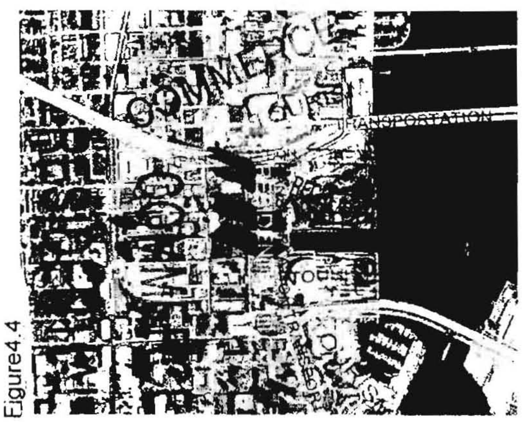


Figure4.4

transportation hubs. As development and economic activity in coastal areas have increased, so has societal vulnerability to coastal hazards. A report compiled by the Union of Concerned Scientist on the ecological risks of climate change states that sea-level rise will increase the rate of beach erosion, which is already a significant threat to homes, roads, industrial facilities, and other infrastructure along the shorefront. The report goes on to describe other threats that include the diminishing of species and habitats, changing rainfall patterns, changes in frequency and intensity of storms resulting in economic losses from damages ("Florida Climate Projections"). The effects of the environmental threats from climate change will have significant effects on Miami's natural systems the goods and services they provide, which will have a critical impact on sustaining the local economy.

The Intergovernmental Panel on Climate Change (IPCC) examined a series of climate simulations from modeling centers around the world for both trends and variability (IPCC 2007). These simulations mirrored the results of other resources in the rise of sea-level, erosion of beaches, increase of storm duration and intensity of storms, and diminishing of ecosystems and habitats. On top of environmental threats due to climate change, the IPCC also projects a 12% increase in population for Miami, Florida in the next fifty years (IPCC 2007). Any threats projected for this area from climate change will only be exacerbated with the increase in population and development to sustain the influx of population.

The entire state of Florida, especially the coastal regions, are very susceptible to flooding due to the land laying so low to sea level. Miami is on average only 72 inches (7 feet) above sea-level. The underground water supply is just below the ground surface which leaves the water nowhere to drain. The IPCC models project a 4 to 9 inch rise in sea-level by mid-century, and from 9 to 17 inches (low emissions) or 11 to 22 (high emissions) by the end of the century for Miami, Florida. These projections are considered conservative estimates by most though because they exclude recent observations of accelerated melting of glaciers and ice sheets. A more recent Climate Change Science Compendium prepares by the United Nations Environmental Program suggests that sea levels could rise by 20 to 55 inches (UNEP 2009).

Although there is some disagreement on the amount of sea-level rise, it is understood that some level of sea-level rise will occur due to climate change. It is also understood that even the more modest projections imply a significant impact on the highly transmissive Biscayne Aquifer and the near-coastal built environment in Miami, Florida, making life in Miami-Dade County extremely difficult.

CONCLUSION

An intensive review of relevant literature indicates that design, specifically resilient design, can play a vital role in a community's ability to resist damage from natural disasters. Although other factors must be addressed, there is a lot of evidence supporting the fact that community planning can drastically increase a cities ability to not only avoid severe damage, but could optimize on nature's expected flooding of the floodplain. With a combination of strategic and smart building plans and ecological designs relating to natural systems, an urban area could optimize and profit from working with natural systems.

PROBLEM STATEMENT

How can site design focused on ecological solutions and resilient design restore and improve water resources and natural habitat for communities while mitigating threats of extreme weather consequences from intense development on vulnerable coastlines and climate change? How can natural systems be implemented to blend within an urban context?

How does site design contribute to resilience or vulnerability?

- How do the landscape and landscape processes function?
- What are the major concerns related to coastal flooding?

How does the understanding of landscape structure, processes, and change inform the resolution of spatial problems arising from human-nature dialect?

- What are elements that constitute a successful natural landscape area?
- Why choose resilient design over sustainable design?
- How does resilient design weave together human communities and natural ecosystems?

What can be learned from past disaster mitigation efforts?

- What existing disaster mitigation strategies are successful?

SIG

In 2011, there was a record number of tornadoes, unprecedented flooding, rampant earthquakes, disturbing volcanic eruptions and a devastating tsunami in Japan no one will soon forget. Over the past several years, the media has been laden with stories of devastating storms destroying city after city. This increase and exposure of natural disasters uncovered a need to create a new arm in the field of landscape architecture. The need for emergency designing and disaster planning in the form of resilient design is necessary due to the increasing change in weather patterns and sea level rise.

The focus of this study is on resilient design in urban areas. Specifically, it investigates intense development of the static environment on the coast of Miami, Florida, considering the natural shifting landscape of its coast. Two priorities to be addressed in this study include megacities and water. The challenge of megacities is that of how to design for intense human development in one compact area while letting natural systems work properly. The second priority is water as the world's most vital resource. However, it is both a resource and a threat. Water is central to every aspect of city life: from basic human sustenance and public health to environmental remediation and overall urban renewal. However, water can also wipeout a community if not treated as such a vital human necessity. With the threat of sea level rise from climate change, coastal cities are in danger of experiencing abrupt coastal flooding. Miami is ranked the highest U.S. coastal city at risk of exposure of assets and population to coastal flooding when related to climate change and socioeconomic change (OECD). Miami and its reliance on surrounding water bodies is why it is the focus of this study.

This research study proposes to explore how humans have amplified natural hazards where natural environments have been imposed upon as well as to provide a solution to prevent the damages of natural disasters. The goal of the research is to find a solution that combines the static built environment with the dynamic landscape while still providing a high quality of life for the surrounding communities. Using ecological design strategies to apply a preventative shield against future natural threats will allow already built high density development in the vulnerable area of the Miami coastline a chance of survival against the threat of coastal flooding.

GOALS AND OBJECTIVES

1) Mitigate the Environmental Impacts that Intense Anthropogenic Development has had on the Natural Coast and React to Climate Change Threats

Goal: Create Waterfront for All
- Objective: Design waterfront to feel and function as part of city fabric
- Objective: Allow for designated areas of different activities, but also create separation.

Goal: Put shoreline & innovative, sustainable design at forefront
- Objective: Protect and re-establish coastline at a regional scale
- Objective: Increase vegetation and ecological reinforcement along bay

Goal: Create a vision that translates, adapts and responds overtime to projected threats, challenges, and changes
- Objective: Implement a design that is able to respond to daily tidal patterns as well as 100-year extreme storm events

2) Cohesively combine natural areas with built environment

Goal: Reconnect city to its waterfront
- Objective: "Break through" the Biscayne Wall
- Objective: Create green belt to surrounding parks
- Objective: Draw residents and tourists to site

Goal: Embrace, celebrate & plan for Miami present, past & future
- Objective: Use vegetation and circulation to create a natural experience through the built environment
- Objective: Integrate alternative building uses to help with social interaction
- Objective: Utilize consistent themes of native plantings that work within the system to create a reoccurring concept throughout the landscape

SITE ISSUES

Flooding:

Over half of the site was located in a flood plain and experienced flooding seasonally - during the wet season - as well as daily due to high and low tidal patterns. The western section of the site experienced sitting water because of the lack of green, infiltration space and Miami's high ground water level. The entire site was threatened during large rainstorms or surges such as a 50- or 100-year rain event. This issue created a large challenge when designing the site, but also allowed for new opportunities with ecological approaches and technological solutions to celebrate the coastline and transition of water in very creative ways.

Public access:

While the park was used for some festivities and events, it was highly underutilized for the location and density of the surrounding area. There were several public transportation routes going through the site including light rail and bus transport. If the site flooded, only the light rail was available for use. Wide sidewalks along Biscayne Boulevard provided areas for bicycles and pedestrian use. None of the other sidewalks on site provided this ease of access for pedestrians. The high rises on site took away all sense of the human scale and made the empty lots and hardscapes feel even more uncomfortable for pedestrians. Bringing the scale back to pedestrian level and focusing on creating a space for all users was the huge challenge of the design.

Natural systems:

Due to the high amount of development on the site, the natural systems experienced a high level of abuse. Degradation of both terrestrial and aquatic life had a negative impact on the entire site. Loss of the natural mangroves and aquatic ecosystems put even more pressure on the coastline and structural sea wall. The urban runoff from existing infrastructure ran directly into the bay without any potential for remediation. This hurt the life and quality of the bay even further. By implementing more natural systems into the design, the site was protected from sea-level rise and storm surges.

Land use:

The site was large and designated residential high rises occupied a fourth of the site. Six vacant blocks on the western section of the site were an eye-sore and were underutilized much of the time. New development had to be built to code for salt water intrusion and storm surges. Minimal development was allowed and no development was allowed within a specific buffer around the coastline.

Connectivity:

Because of the high volume traffic through the site and on the northern and southern boundaries of the site, connectivity was a huge problem. There was not only a need for connections to the site from the surrounding context, but it was also central to the idea to connect spaces and places within the site so that it acted as one landscape. Further analysis showed different techniques as well as the successfulness of specific links.

CLIENTS

Clients and users of the space included the people of the city of Miami as well as species of animals and birds that would be revitalized due to the increase in habitat. Other specific entities included government officials, park board members, private business developers, potential residents, tourists, museum board members and visitors.

PROGRAM

DESIGN GUIDELINES

Design Theme

The design theme for the Museum Park located in Miami, Florida was to re-establish the native ecosystems and wildlife in order to reinforce the strength of the coastline and protect the city from flood threats. As part of the Biscayne Watershed, this site was characteristic of habitats and ecology that is similar to the Everglades of southern Florida today. Much of the land was drained, filled, and settled once settlement began in the United States. The mangroves and other vegetation that used to line the coast protected the coast from damage from tidal floods, storm surges, and rain events. The design represented a meshing of the natural vegetative ecosystem that used to exist and the modern, innovative development of today. Large-scale implementations such as hardscape materials and plantings represented the modern development while the small-scale elements such as curvilinear, organic patterns represented native ecosystems. This theme continued to be the guide for future modifications of the site and detailing.

Water and Hydrology

- Reintroduced mangrove forest to coastline in order to harvest sedimentation from runoff and protect inland from storm surges.
- Remediated runoff water from raised topography areas through gabion walls and loose aggregate that would flow to water storage tanks.
- Incorporated water storage under new areas of topography.
- Implemented rain harvesting on all new development.
- Minimized the areas of impervious surface in order to reduce runoff.
- Implemented wetland retention areas with runoff treatment facilities to ensure high water quality. Possibilities included bioswales, natural treatment ponds, and impervious lined channels planted with indigenous materials.
- All urban areas included a stormwater collection and treatment system using BMPs.

Vegetation

Protection of Existing Vegetation

- Preserved large trees wherever possible.
- Protected native seedling and sampling trees.

Re-vegetation of Disturbed Areas

- Developed detailed re-vegetation plans for areas of special concern, specifically the coast
- Used only indigenous plant materials for re-vegetation of disturbed areas.
- Specified the use of erosion control vegetation on areas of slope and along the roadway to prevent the establishment of invasive species.
- Made special effort to salvage and reuse topsoil.
- Used a mix of successional stage species to leave the disturbed area looking much like the adjacent natural

environment.

Planting Design

- Provided vegetation through riparian areas to provide cover for wildlife.
- Used only indigenous species.
- Selected plants that can withstand wet feet in areas designated to flood.
- Specified plants on slopes that can be used to filter storm water.

Building and Land Use

- All new development must be built to meet LEED GB as well as be able to withstand salt water intrusion.
- All new development must be built to code to withstand storm surges and storm events.
- All new buildings shall be mixed-use.

With such an open piece of land, available for manipulation, the designer began with a broad scope of contextual elements that surrounded the site. Understanding the connection to the surrounding context, whether it be on foot, bicycle, car, or public transportation, was important. Along with locating city parks and important institutions, an overall re-creation of mangroves along the coast could connect the site to the rest of coastal areas and downtown. Although connection was a large design element, the main priority was solutions to prevent or resist flooding.

Initial conceptual designs were a direct result of applying different techniques to resist floods from sea level rise and rain events. No solution presented an overall theme or big idea that would solve the issue of protecting the inland site. Upon further research, the designer identified what ecology existed in its natural state: mangroves.

This realization began to form a more defined solution with re-establishing past ecosystems. Previously existing ecosystems combined with new technology could create a strong force against any unknown flood threat. With that knowledge, site details and elements began to take place. These started to give life to the design as it was continually refined.

SITE LOCATION

Climate, weather, and especially flooding were influenced by the way that communities and urban infrastructure were designed and built. Coastal and water-edge properties had high population density and property values. One of the fastest growing coastal cities was Miami in Miami-Dade County, Florida. Population growth of this coastal county continued to increase due to its market attractiveness and lifestyle choice of affluent living. Miami was an older city which represented the colonial and nineteenth-century maritime history and had some long-established infrastructure of ports, harbors, railway, roads, and bridges. Because of its high population density and older intense urban infrastructure, Miami was a hot-spot location for resilient design. Figure5 shows the core project area in relation to the rest of Miami.

Figure5

Biscayne Boulevard, downtown Miami's "main street," was the central axis for this site with the northern boundary being the MacArthur Causeway and Port Boulevard being the boundary to the south. Six underutilized blocks from 1st Avenue to the west were revitalized using ecological design elements in order to create a resilient design in this vulnerable area. The eastern boundary of the study area was Biscayne Bay with Bicentennial Park and AmericanAirlines Arena being in between the two outlying boundaries as seen in Figure6. Other than seasonal and sporting events, the site was highly underutilized for such a dense area of the city.

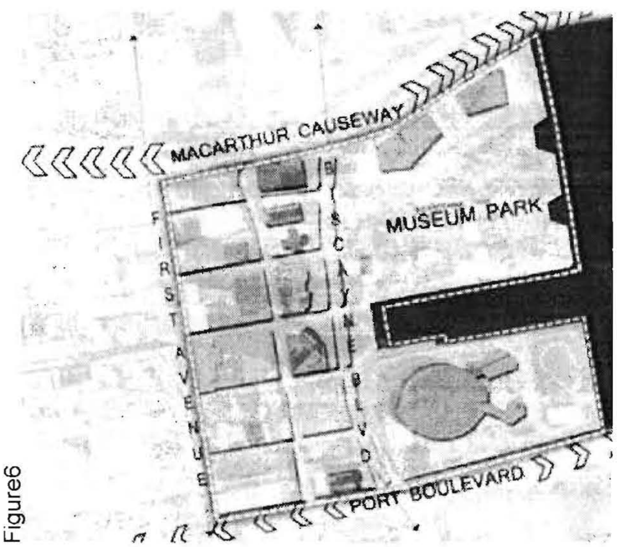


Figure6

Miami served as one of the most diverse populations in one of the fastest growing regions in the country, where a unique confluence of Caribbean, North and South American cultures added vibrancy and texture to the civic landscape. With a combination of city proposals and new resilient ecological designs, this area could become a bustling area that promoted progressive arts, education, community cohesiveness, and contributed to a sustainable ecosystem both in the natural habitat and the urban context. The progress and creativity in the institutions and resilient design of the landscape reshaped the image and reality of this international gateway city and served as an example for other cities.

Only four blocks south of the site was Miami's largest park: Bayfront. This park was a 32-acre site and was located in the epicenter of downtown Miami. Within the park was Bayside Marketplace, an open-air festival-style mall that attracts over 12 million people per year. The location to this highly used park provided a great opportunity for the city of Miami to create a greenway corridor along the bay linking the Bayfront Park to Bicentennial Park while emphasizing an area of resilient design in a highly dense and vulnerable area. The chosen site's proximity to other major attractions in Miami is shown in Figure7.

Bicentennial Park, a 30-acre public, urban park was the central design point of this study area. This park was undergoing a renovation to be renamed Museum Park for the construction of the new Miami Art Museum and Miami Science Museum which were to be built on the site. Renovations included a complete revamp of the park as it was underutilized for a large portion of the year. The new museums anchored the park overlooking Biscayne Bay and included public gardens, sculpture installations and plaza areas. The renovations to these buildings and park served as a catalyst in efforts to strengthen Miami's momentum as an emerging global capital. Both energy-efficient buildings served as inspiration to complete a resilient and ecologically friendly landscape to match the world class buildings.

The site also included the area directly to the south encompassing AmericanAirlines Arena which is a sports and entertainment arena and home to the NBA team, the Miami Heat. It also houses the Waterfront Theater, Florida's largest theater which was housed within the arena. The arena is directly served by Miami-Dade County public transportation in the form of Miami Metrorail, Metromover, Tri-Rail, and Metrobus making this site highly accessible. Port Boulevard served as a barrier between the arena and Bayfront Park. However, with AmericanAirlines Arena location abutting Bayfront Bay, a connection of greenways from Bayfront Park through the arena and to Museum Park would increase the ecological system and add to the resilient design.

Directly to the west, Museum Park was cut off from the rest of downtown by the Biscayne Wall. This barricade referred to a wall of skyscrapers on the west side of Biscayne Boulevard shown in Image1. The four residential skyscrapers were dramatically out of scale from the surrounding context. However, these properties served as high value real-estate for their great views into the bay and coastline. Beyond the Biscayne Wall were blocks of underutilized parking. According to reports on the Miami-Dade County Municipal website, these blocks

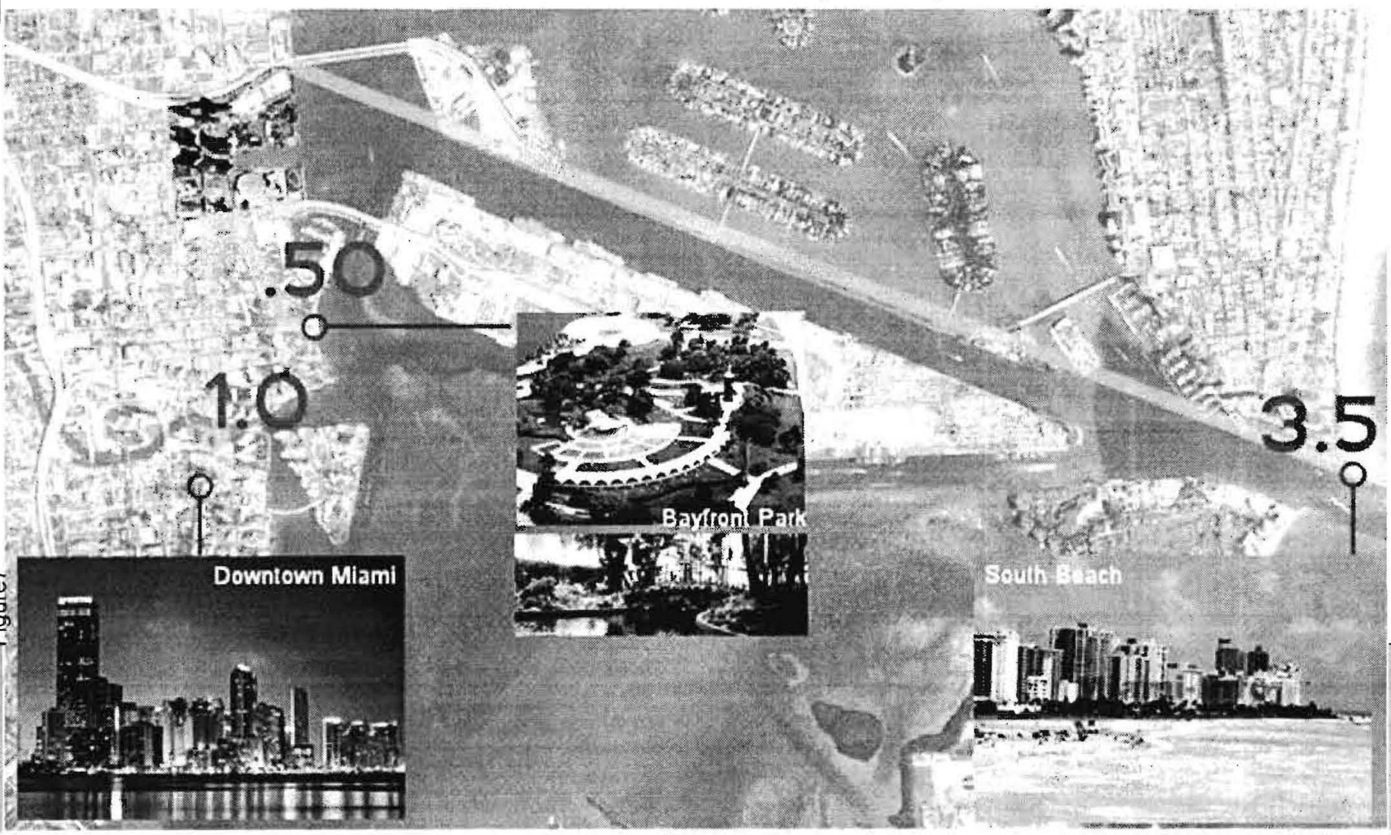


Figure7

were still within the flood plain that required planning shown in Figure8.

Biscayne Bay was divided into three parts and was approximately thirty-five miles in length. This site is within North Bay. North Bay accounted for only 10% of the water area of the bay, but had the most anthropogenic actions. It had been severely affected by sewage releases, urban runoff, shoreline bulk-heading, dredging, the creation of artificial islands, and the loss of natural fresh water flow into the bay. The bay would be celebrated and emphasized in this design while providing natural defenses to flooding. With no direct access to the bay available on this site, a new design called for opportunities to access the water with ecological designs that will help to resist flooding and capture and clean storm water runoff.

The concurrence of freshwater and saltwater would be largely affected with even a slight sea level rise through natural systems of coastal marshes, beach strands, and seabeds. Because of the lack of topography on this site shown in Figure9, even a very slight rise in sea level would increase saltwater intrusion into the current aquifers that hold the fresh water, such that salt water would percolate upwards into shallow freshwater aquifers. In order to prevent such dangers, resilient design would need to be implemented. This site provided a perfect slate for promoting education with sustainable, ecological-based, resilient design on a scale that would provide protection for a vulnerable city while connecting to the surrounding urban context.

Image1

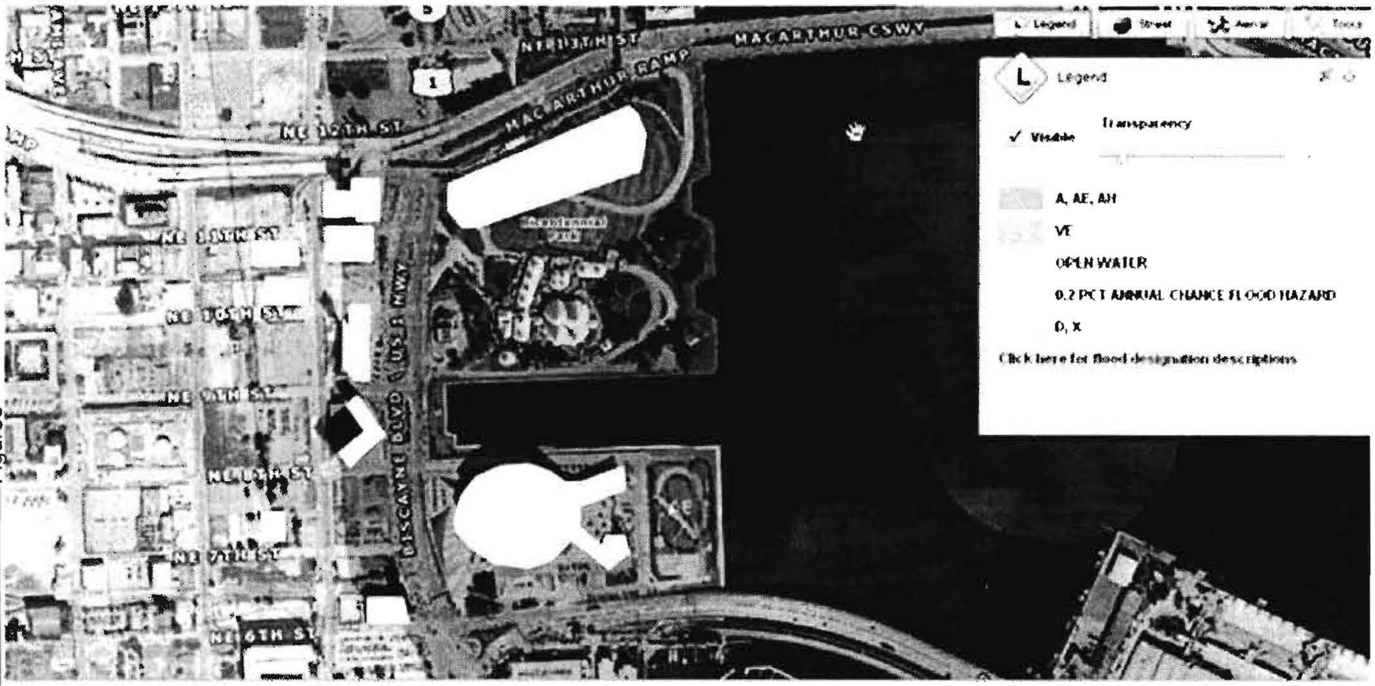


Figure8

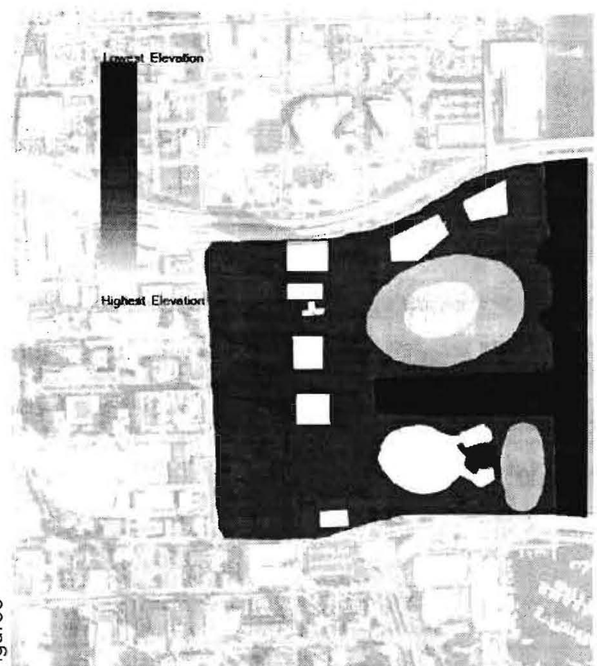


Figure9

Figure10 shows the surrounding regional context that provided several areas of public park space and areas that attract tourism. While there was not a shortage of park or community space, there was no connection between them—especially along the coast. This left little to no movement between spaces and did not inspire community connectivity.

Vehicular circulation was in excess surrounding the site, which promoted travel to other areas around Miami, but did not allow for travel within the site, particularly pedestrian movement.

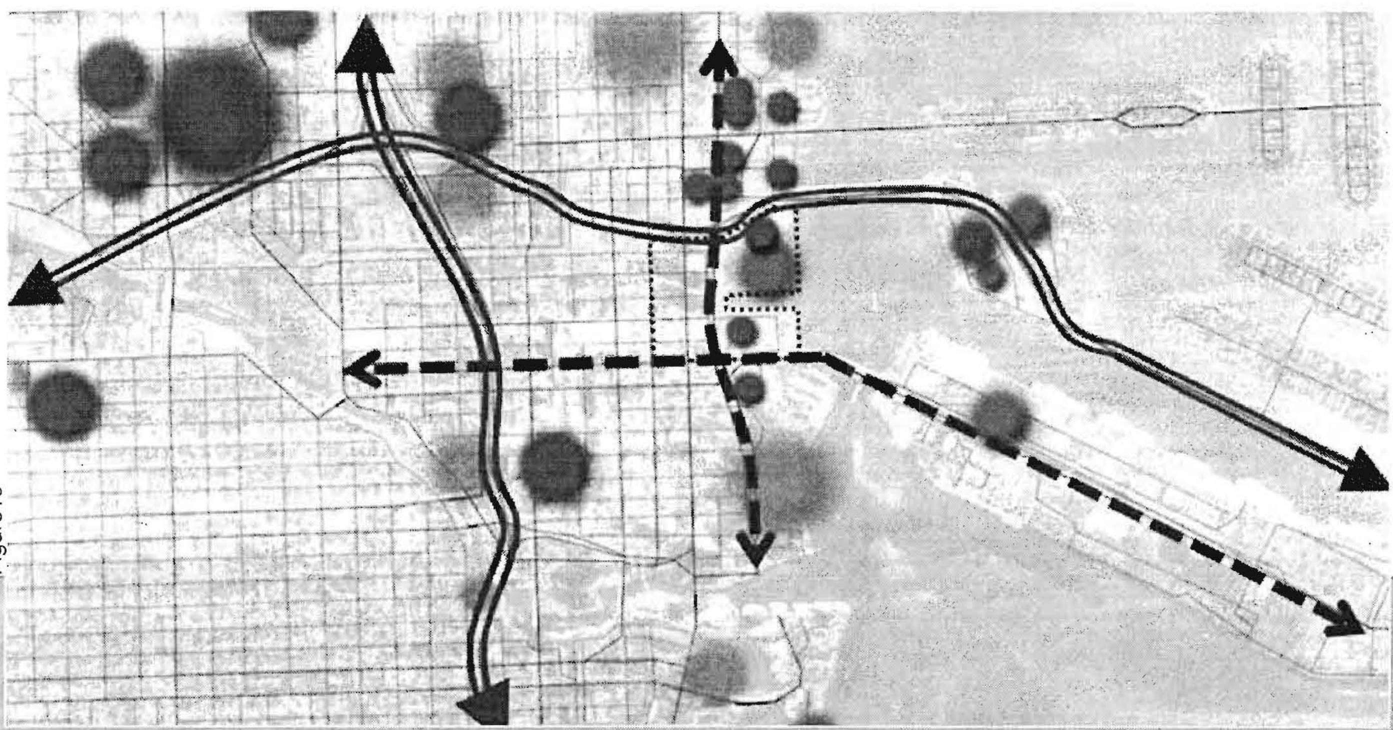


Figure10

SITE INVENTORY

It was critical to identify the positive opportunities and weaknesses of the site. There were several circulation patterns that existed in the area. There was a major interstate just north of the site that transports travelers to South Beach. This roadway experienced heavy traffic at all times during the day. Biscayne Boulevard acted as the central axis in the site, splitting the site into two different areas. Pedestrian traffic was promoted along the boulevard with wide sidewalks and a unique paving pattern shown in Figure11 and Figure12.

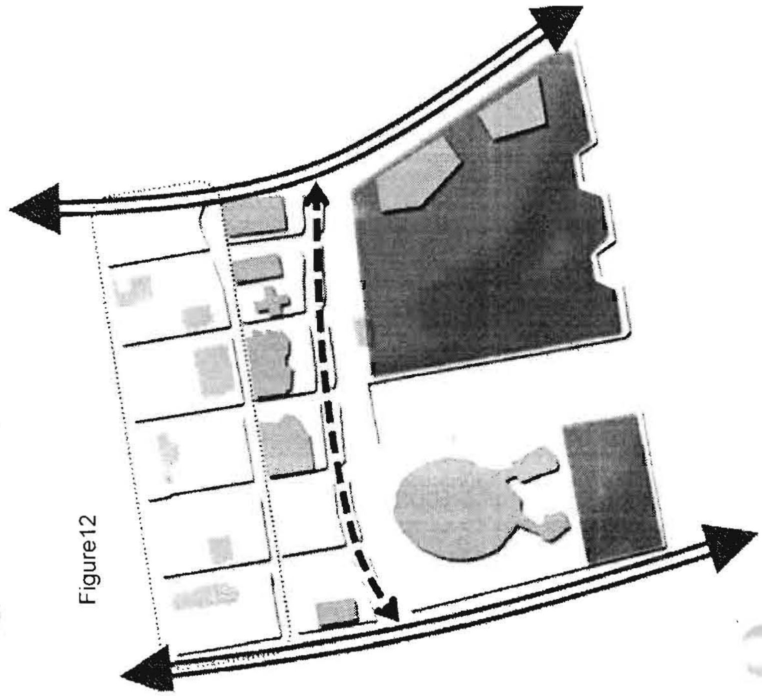


Figure12

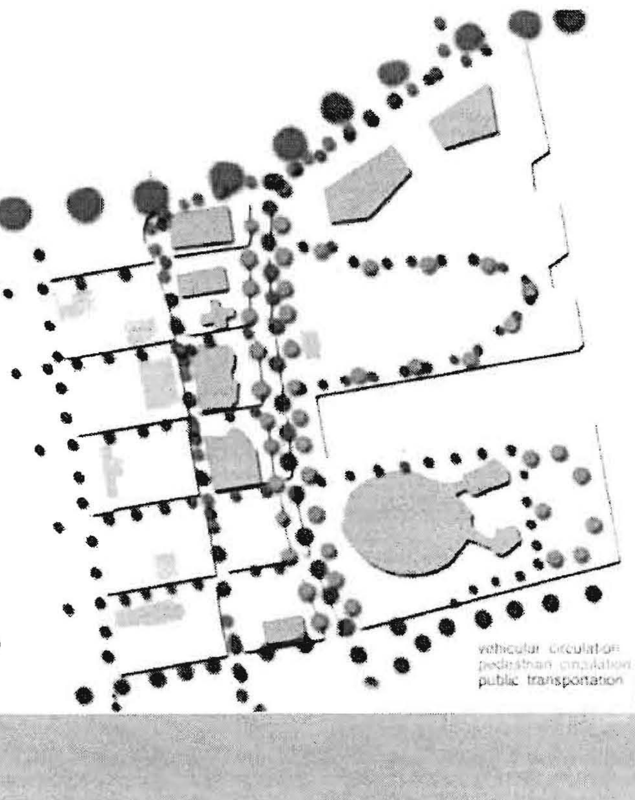


Figure11

There was plenty of open space available on site for manipulation. However, this area was man-made infill and did not naturally exist. The implementation of sea wall had protected the site from flood intrusion. This was the only space in the northern part of the bay that had an all man-made structure protecting the coast line shown in Figure13. Sections show the availability of access when ecological reinforcement is used to help strengthen a sea wall.

The sea wall kept the site protected from flooding currently. However, with the projected rise in sea level that was predicted from IPCC the sea wall would no longer keep the site free of sea water. The projections called for a rise in sea level anywhere from 27 inches to 55 inches. The wall was only 3 feet above the average tide level. With the site only an average of 7 feet above sea level, the increase in sea rise would devastate the entire site.

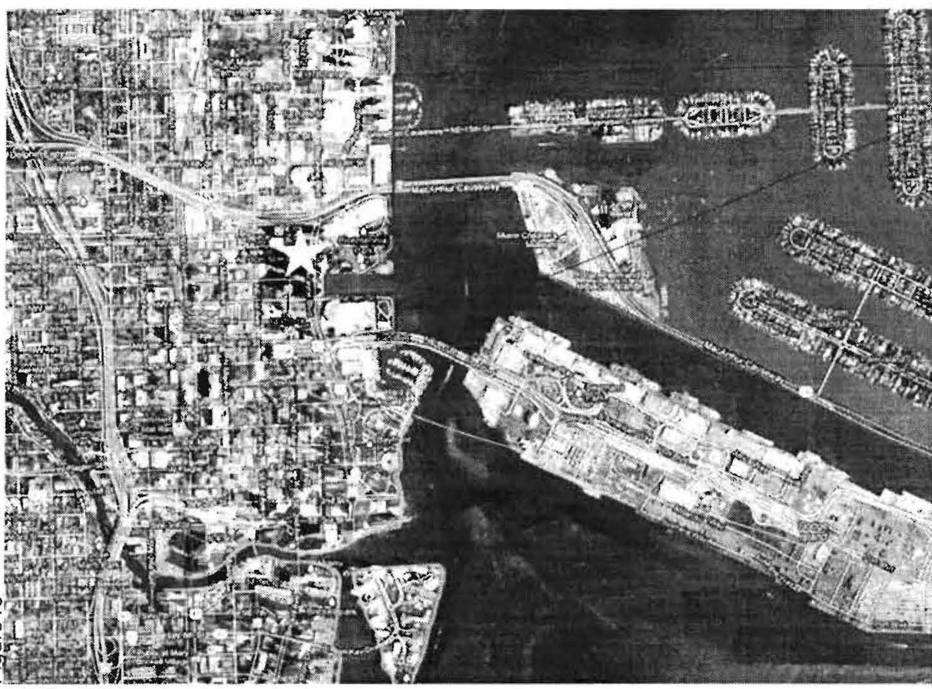


Figure13

Section of site with only sea wall

Section of site with ecological reinforcement

SITE INVENTORY

daily
yearly
10-year storm
50-year storm

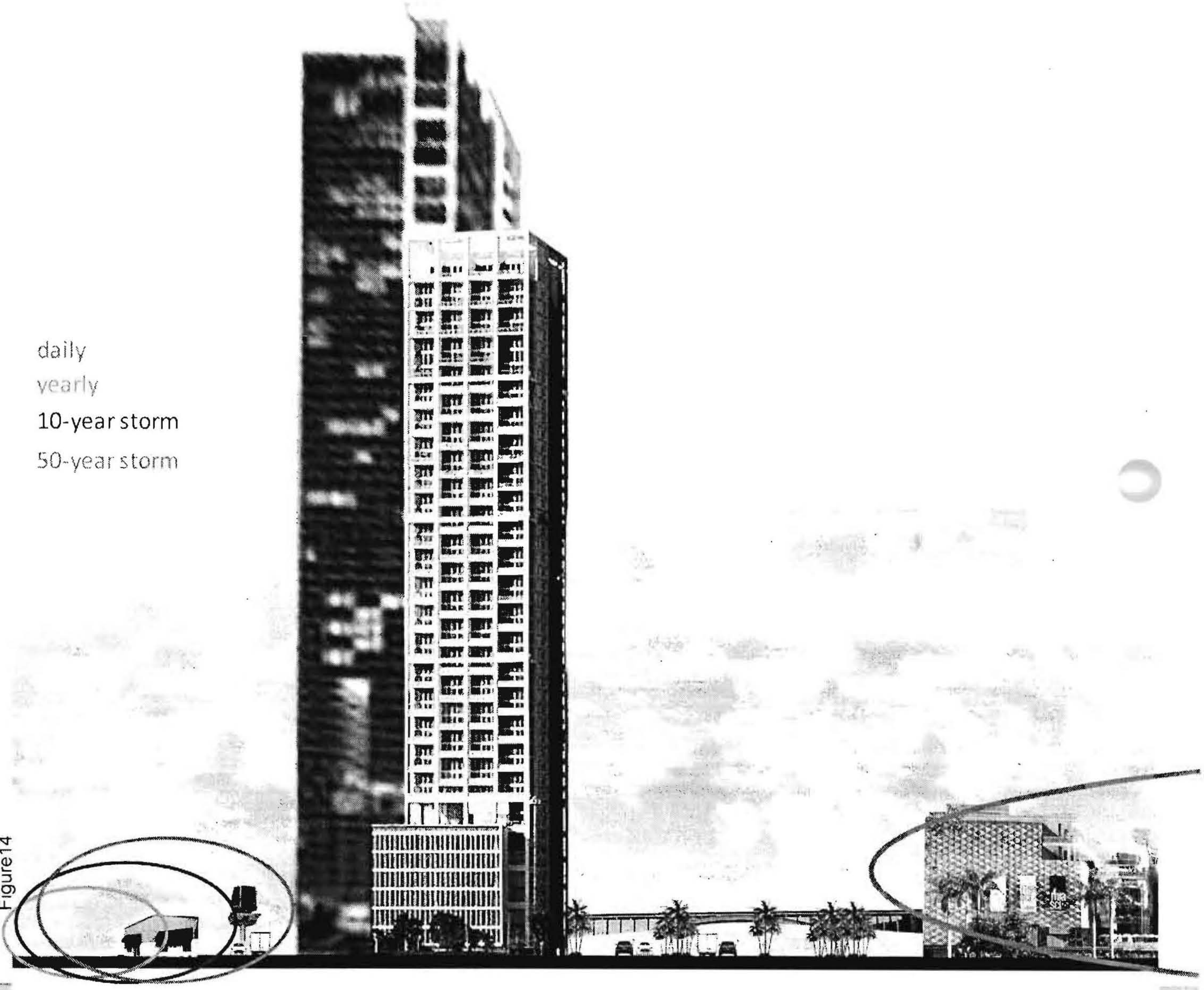


Figure14

Figure14 depicts a site section from West to East. The site had little to no rise in topography. This provided no protection to flood from sea level rise or storm events. Figure14 also shows where different intensities of storm events would impact the site as it was. Majority of the site would be threatened if some type of implementation would not be installed. Daily tides would impact the site on the coast edge. Yearly rain patterns threatened the site because there was nowhere for high quantities of stormwater to drain due to the high water tables. Intense storms had the potential to put the majority of the site underwater.

The impact of the projected sea level rise is shown in Figure15. There was about a two foot change from high tide to low tide. The sea wall that was on site would not be able to hold back even the moderate projections.

Figure16 shows how the current site would be impacted from each projected sea level rise if some manipulations were not made to the site. Due to the lack of change in topography, majority of the site would be threatened.

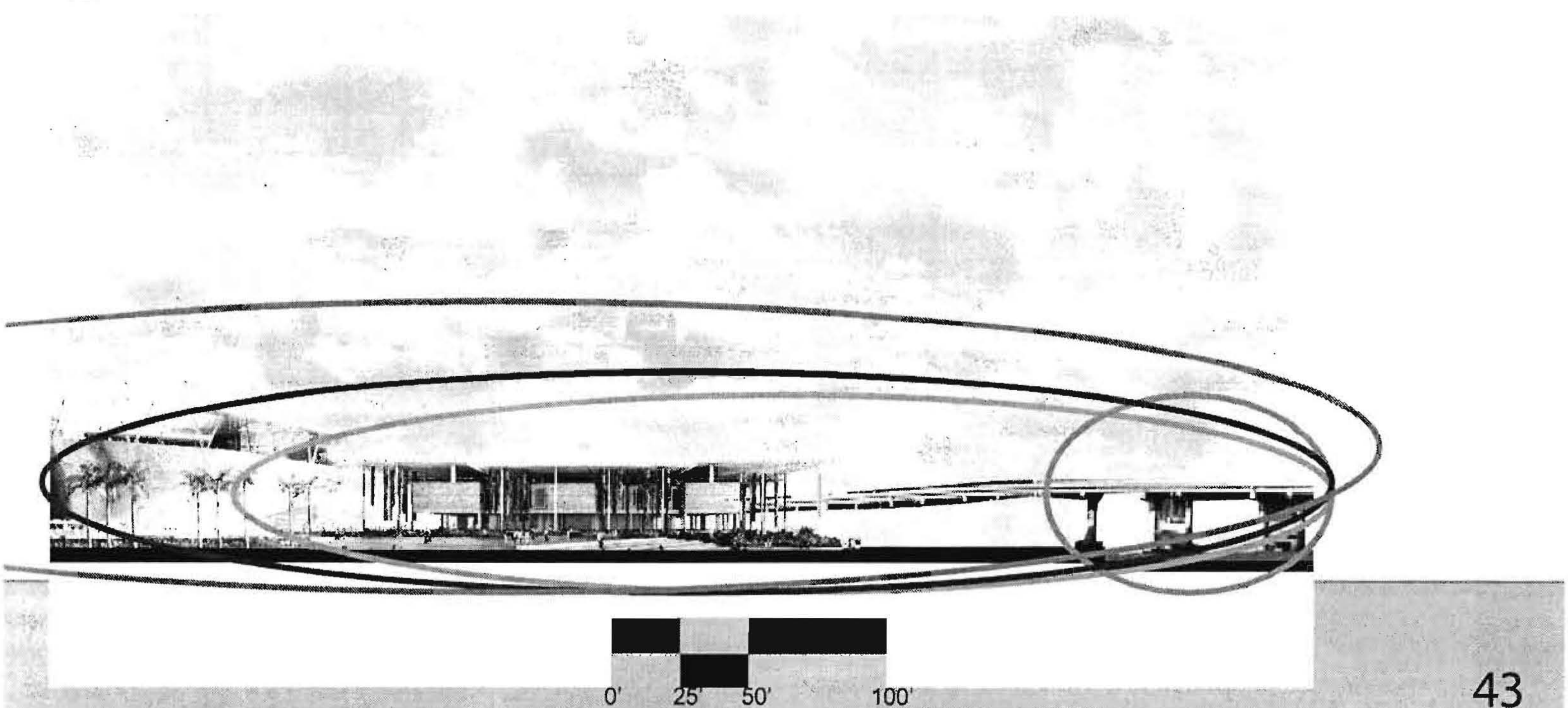


Figure15

Figure16

After identifying the risks and opportunities of the site, it was clear that additional protection from the threat of flooding needed to be implemented. The current sea wall would not be able to support the increase in sea-level rise. It was also deteriorating the current sedimentation that is supporting the wall (Figure17). It was necessary that a solution be implemented that would not only protect the site from flood risk, but would also help to boost the quality of the landform supporting the site. This solution was an approach that will provide structural support while also allowing areas of tidal zones to support ecosystems that will reinforce the strength of the wall while breaking the intensity of the waves crashing against it (Image2).

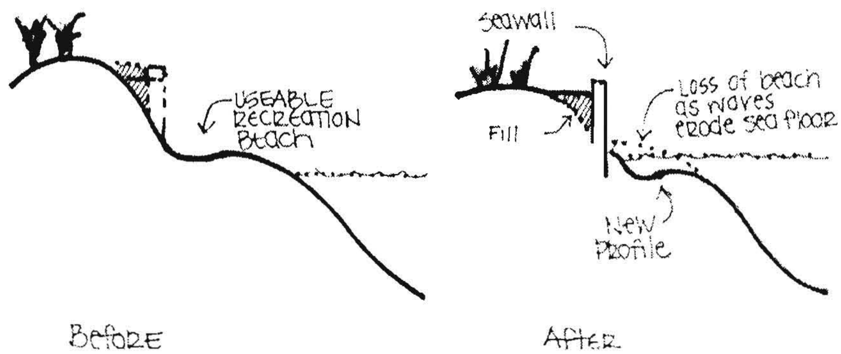


Figure17

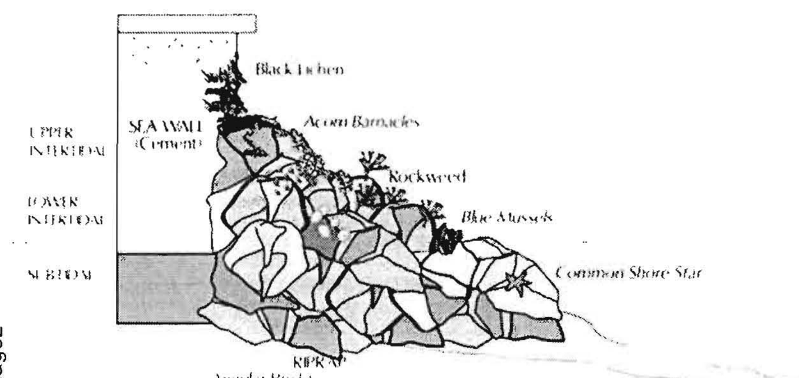


Image2

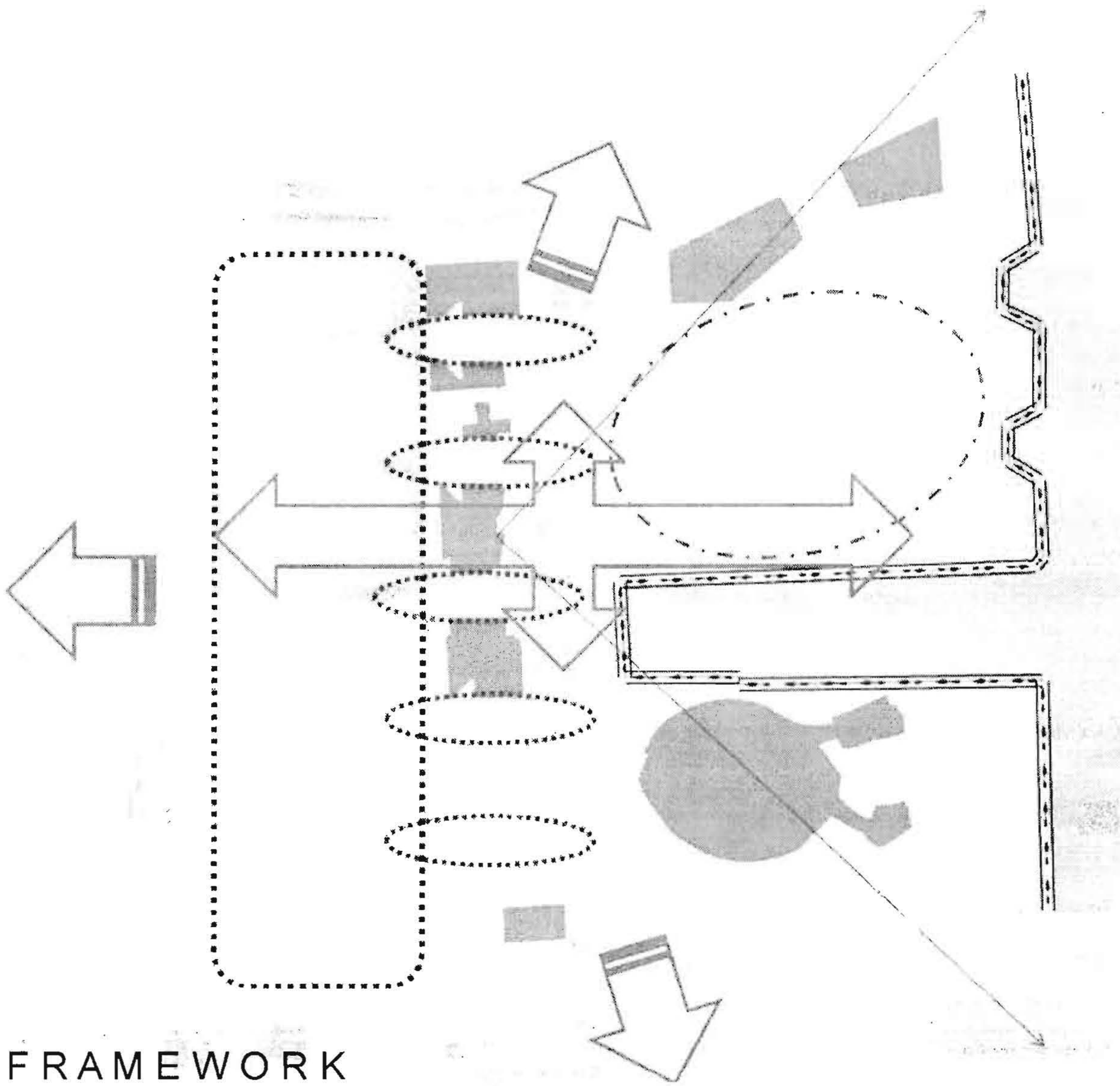
http://www.crd.bc.ca

The implementation of an ecological sea wall would not guarantee that it would translated to protect the site from floods and increase in storm surge. For extra security, the land would need to be built up as well as buildings and entrances raised.

Pedestrian circulation needed to be able to move laterally across the site as well as only North and South. Visual and physical access needed to be available through the wall of high rise residential towers called the "Biscayne Wall." Due to the amount of tourist and commerce areas on the site, safe pedestrian movement needed to be available throughout the site to promote an area that people will come to explore.

The six blocks of empty parking lots could be used as areas of development for the increase in population projected. Some of the lots could be used as areas of implemented green infrastructure to manage the storm water runoff from the surrounding developed areas to decrease possibilities of overflow flooding.

A green belt could be created on site in order to promote movement between different public and green spaces throughout the regional context.



site FRAMEWORK

PRECEDENT STUDY #1

Pier 1, Brooklyn Bridge Park
Michael Van Valkenburgh Associates, Inc.

With its daily experience with tidal changes, Brooklyn Bridge Pier One was a great example to look at for inspiration in how to handle different tidal patterns and interpret its design as it related to the designer's site. A program of material salvage and reuse supported a sense of waterfront continuity amidst change. Because of its relatively solid foundation and the careful selection of materials, Pier 1 was able to support a robust new site topography that corresponded with its position as an ideal prospect for enjoying city views and the skyline.

Pier 1 was built on all landfill similar to the site area in Miami. Although it was by no means natural, it was a place where city dwellers came to enjoy nature. New complex topography and a diverse matrix of plants interacted with related site systems such as stormwater capture, cleansing, and reuse. With these elements, this project was able to provide 70% of its water needs on site.

Most importantly, Pier 1 created an opportunity to get down to the level of the East River safely. Access areas which lengthened and shortened according to tidal levels, created easy access between the upland and the water's edge.

Lower Don Lands, Toroto Waterfront
Michael Van Valkenburgh Associates, Inc.

The Lower Don Lands was chosen as an inspiration for the designer's site because of its overall success in understanding and combining two of Toronto's dominant park typologies—structural rectilinear parks shaped by the urban grid and organic, irregular parks shaped by the topography of extensive ravines.

Ecological elements were an important focus of the Lower Don Lands. One main element that was emphasized was sedimentation harvesting through meandering streams. Other areas focused on water retention and cleaning of stormwater and several areas focus on different landscape types.

The social program was recognized as important as the ecological one in this project's vision. The Lower Don Lands several areas allowed for a different variety of public activities such as regulation sports, informal pickup games, kite-flying, jogging and in-line skating, bird watching, strolling, and contemplation. Social interaction was promoted through broad tree-lined sidewalks, squares, and community events.

PRECEDENT STUDY #3

Seattle Waterfront
James Corner

The Seattle Waterfront first drew the designer's attention because of the removal of the seawall that lined the coast. From there, it was clear that there were several aspects of the success of Seattle Waterfront that could be translated to the designer's site.

The Seattle Waterfront project succeeded in reconnecting the city with its waterfront. Improved crosswalks and pedestrian passageways increased the amount of public usage of the waterfront.

A continuous walk along the harbor was created in the previously not easily traversed route. This walk took advantage of the wonderful views that the waterfront has to the surrounding context.

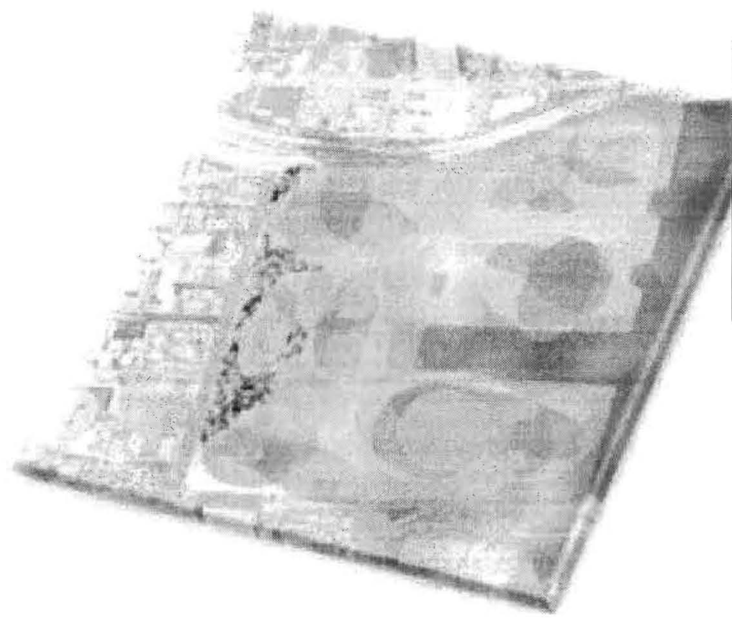
This project was also very successful in reuniting the public with the waterfront. Areas allowed for interaction with the water while still protecting the upland areas with a more natural approach to the coastline. James Corner created an easier grade for pedestrian access to the piers as well as created opportunities for stormwater retention and filtration systems.

http://grist.org

CONCEPT DEVELOPMENT 1

Public Islands

The first design concept took on the challenge of planning for maximum projections of sea level rise. Whether the sea wall was removed or failed, the majority of the site would flood with a 55 inch rise in sea level. With appropriate placement of new sea walls, separate areas of commercial, residential, entertainment and productivity areas would be created.

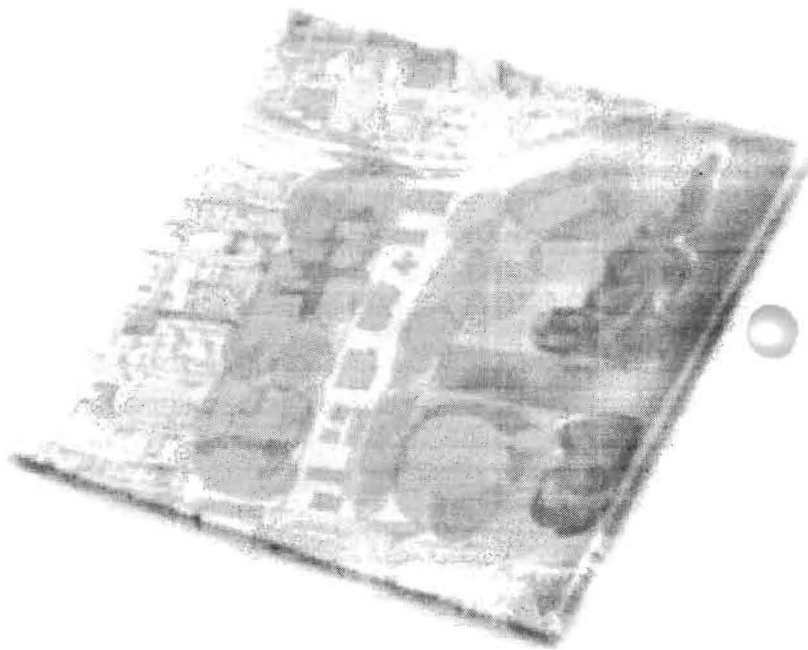


Because sea level rise would be a progressive phenomenon, not occurring all at once, this design did not account for the transitional period between current sea level rise and maximum rise. This design also did not provide suitable transportation between the pods.

CONCEPT DEVELOPMENT 2

Flood Gardens

The second design concept looked at mid-range projections of around 27 inch sea level rise. It focused on keeping the existing sea wall as was but implemented flood prone areas in the design. These landscaped and built areas would withstand saltwater intrusion as well as intense storms. With projected increase in residential and tourist use, implemented green streets and best management practices in green infrastructure would add value to the site.

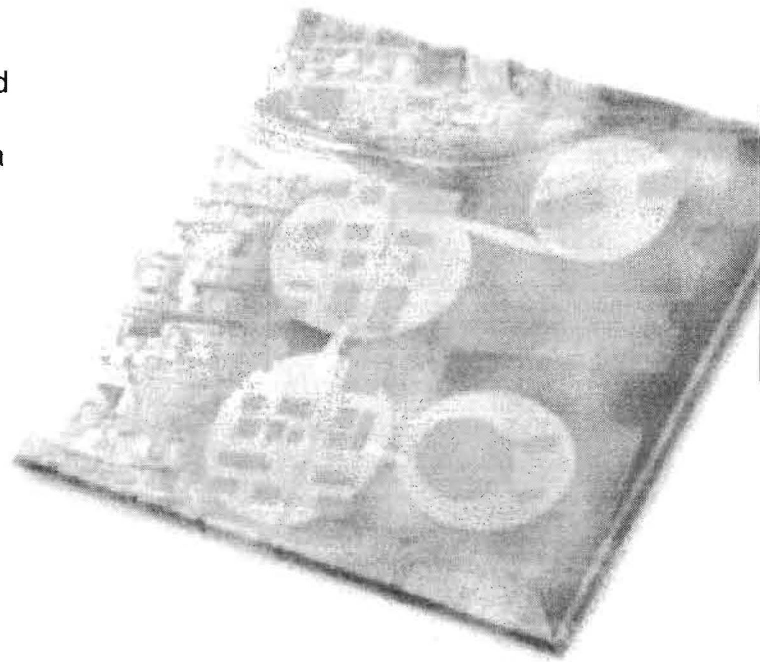


Although this solution would be successful to some level, it did not encompass all elements necessary to create a fully flourishing site. Emphasis needed to be directed to more ecological approaches as well as fulfilling more social needs.

CONCEPT DEVELOPMENT 3

Ecological Restoration

The third design concept highlighted stages of design that would be able to adapt to different levels of threats from sea level rise to storm surges. The sea wall was deconstructed and natural coastline restored. Ecological approaches met technological with natural vegetation and water retention to flood gates and water filtration. Due to unknown threats, second story entries and pedestrian bridges provided access to buildings and activity areas even during flooding.



This solution provided the most comprehensive solution. However, more connections and emphasis on use and access needed to be explored.

MASTER PLAN

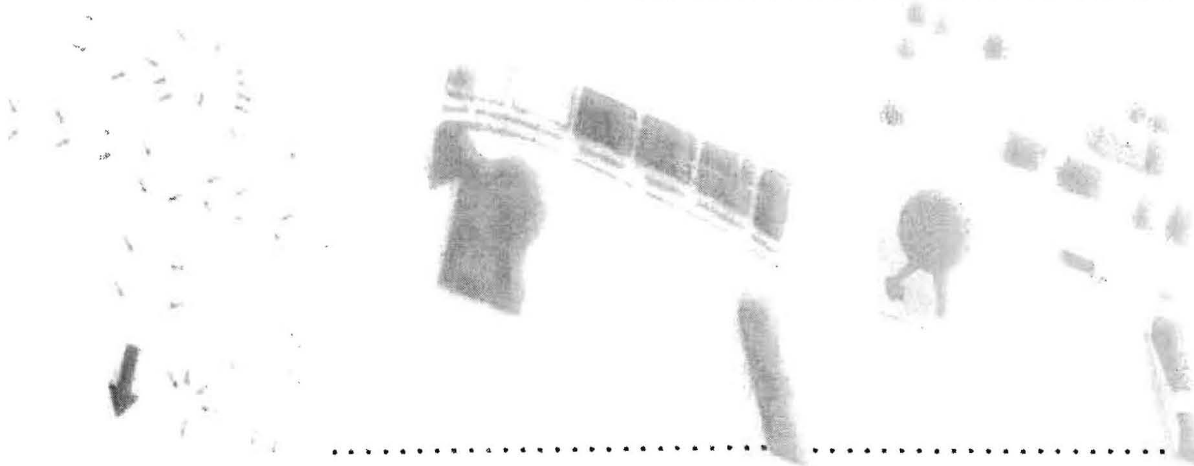
Each idea and concept was an integral part in developing the final master plan for Museum Park and surrounding areas. It was a culmination of each conceptual phase from beginning to end. The main challenge of flooding and development were met in a cohesive design that used water to its fullest capacity, offering visitors the opportunity for interaction and education.

The final product recognized the threats accompanied with climate change and used several ecological implementations in order to be prepared for adaptation to unknown threats. It also restored the natural coast by re-establishing mangroves as a barrier to protect from sea level rise and storm surges.

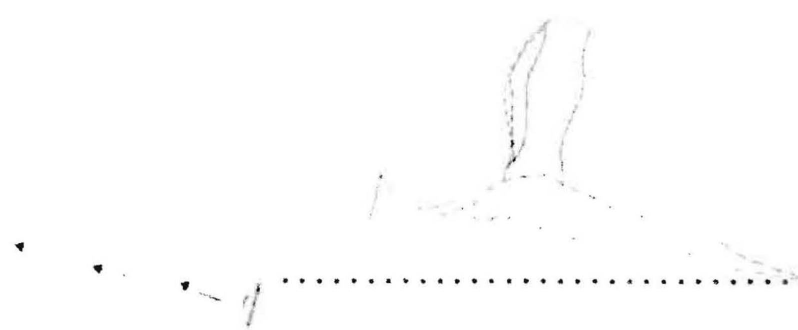
The design came through a unique design and interpretation of open space as well as the modern sustainable technologies that gave this park an ecological solution to flood risk which can protect the upland areas. Overall, its strength came from the protection of the built infrastructure, restoration of natural areas and the meshing of the two while providing safety and access to users.

MASTER plan

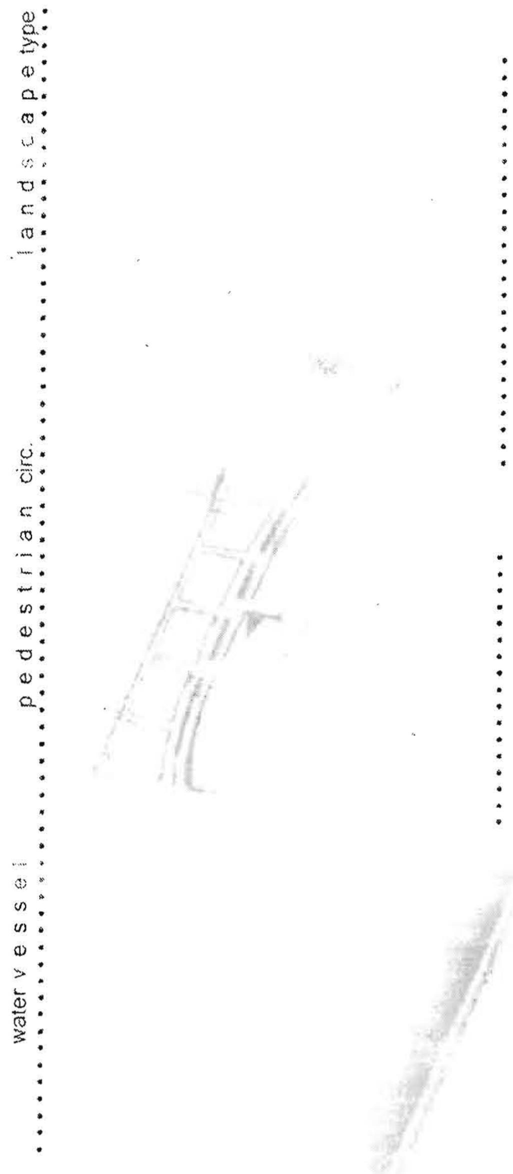
drainage · predesigned · built



sedimentation harvesting · hard vs soft edge



PROGRAM DIAGRAMS

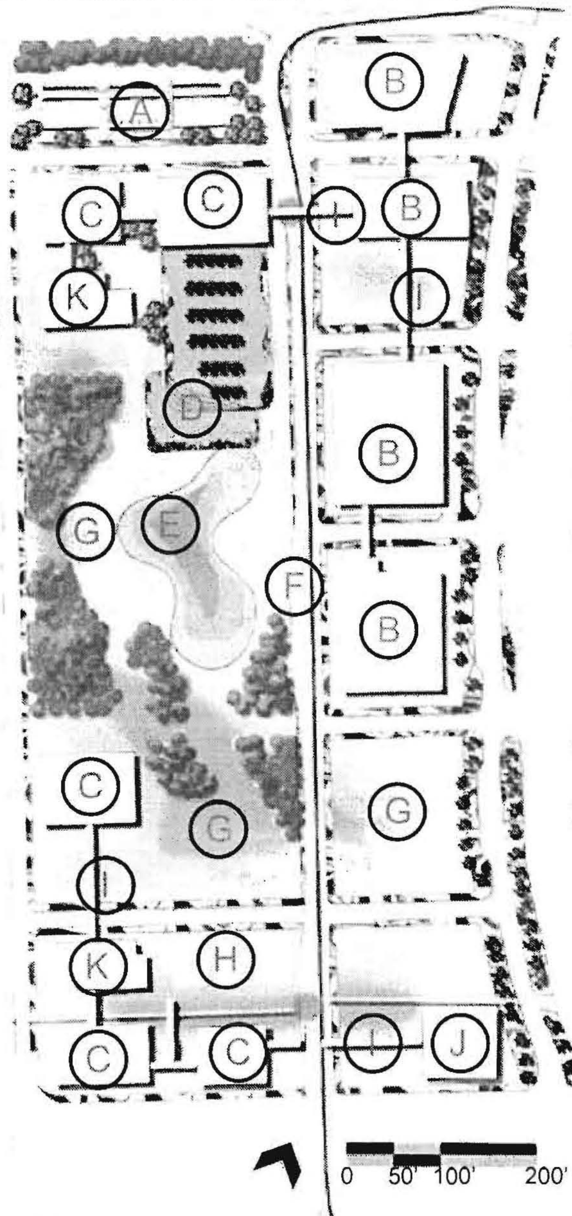


The success of the design was credited to the emphasis put on natural systems. From stormwater retention and filtration to sediment harvesting, this design focused on ecological solutions to reinforce resistance to flood threats. Other successes were owed to the focus on both environmental factors and social aspects such as green space availability and pedestrian circulation.

With some increase in built development to account for the projected increase in population, the site remained mostly green space. The type of landscape varies throughout the site. Landscape types range from areas of heavy vegetation (mangroves) to areas of turf for recreation.

Drainage of stormwater eventually goes through the flood management canal where it goes through several processes of bioremediation before entering Biscayne Bay. During extreme storm events, water was held in several different vessels on the site.

Sediment was trapped and harvested along the coast due to the softening of the edge by the restoration of mangroves. This led to increase of land use by pedestrians and quality of water for Biscayne Bay.



A. Overflow Parking

B. Existing Mixed-Use Residential

C. New Mixed-Use Residential

D. Urban Plaza

E. Retention Wetland

F. Existing Metro

G. Informal Recreation

H. Regulation Fields

I. Pedestrian Bridges

J. Existing Development

K. New Development

L. Relocated Art & Science Museums

M. Existing Metro

N. Gardens in Flood Zone

O. Informal Ampitheater

P. Education Center

Q. Mangroves

R. Floating Walkways

S. Pedestrian Bridges

T. Flood Gates

U. Pedestrian Access

V. Boardwalk

W. New Welcome Center

X. American Airlines Arena

Y. Flood Management Canal

Z. Underground Parking

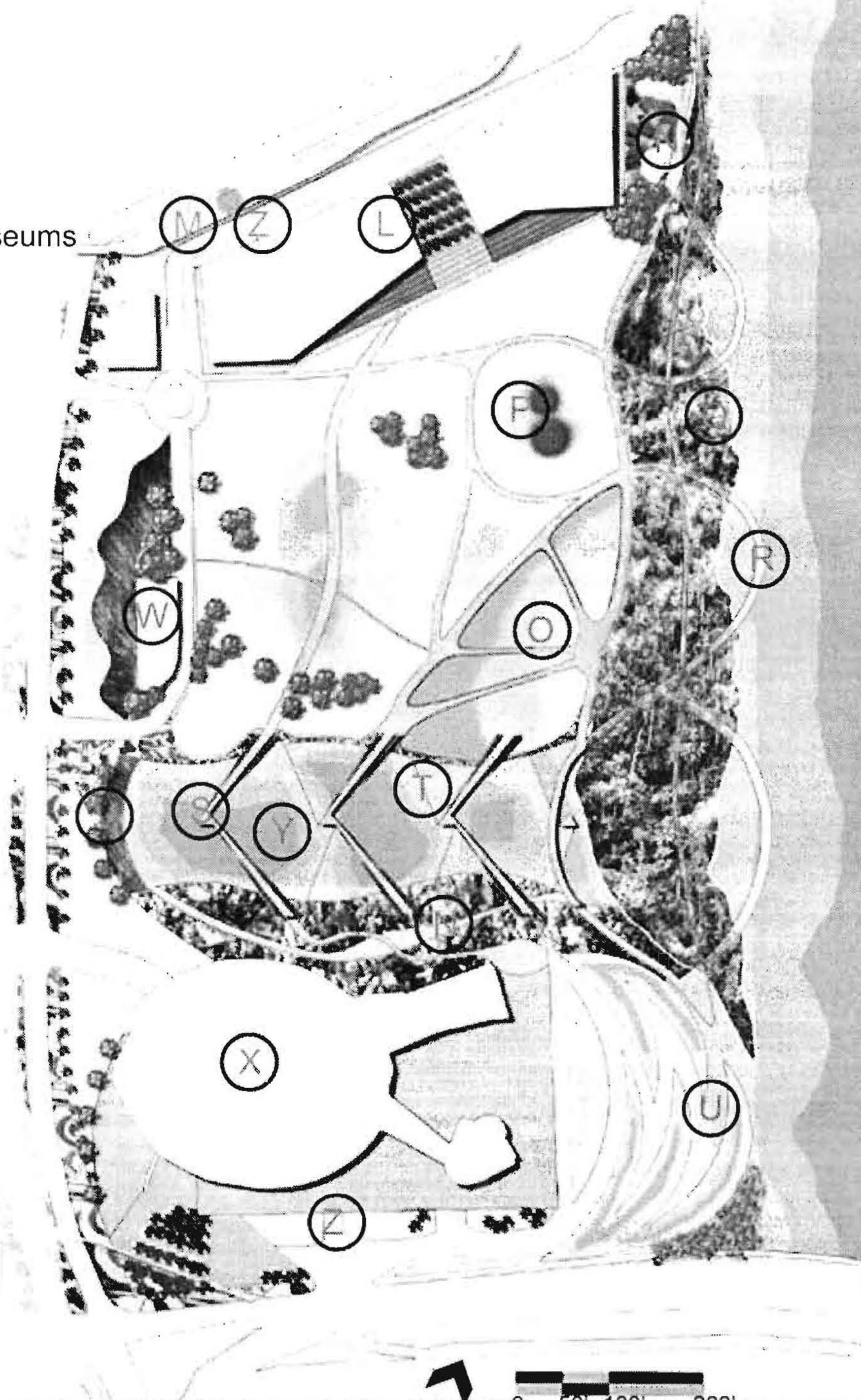


Figure18 and Figure19 show flood risks for the implemented design. Although some flooding was inevitable, the site was controlled and able to adapt to the different levels of threat. The re-established mangroves controlled the daily and yearly tidal patterns while taking the main impact of storm events. Designated areas on site will flood during rain events, but will be able to re-enter ground water after being remediated. This design succeeded in protecting the infrastructure and population from damages due to flooding.

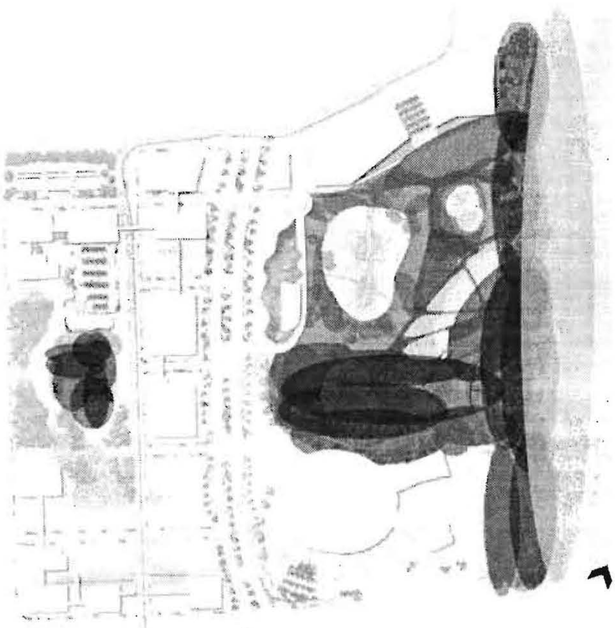


Figure18

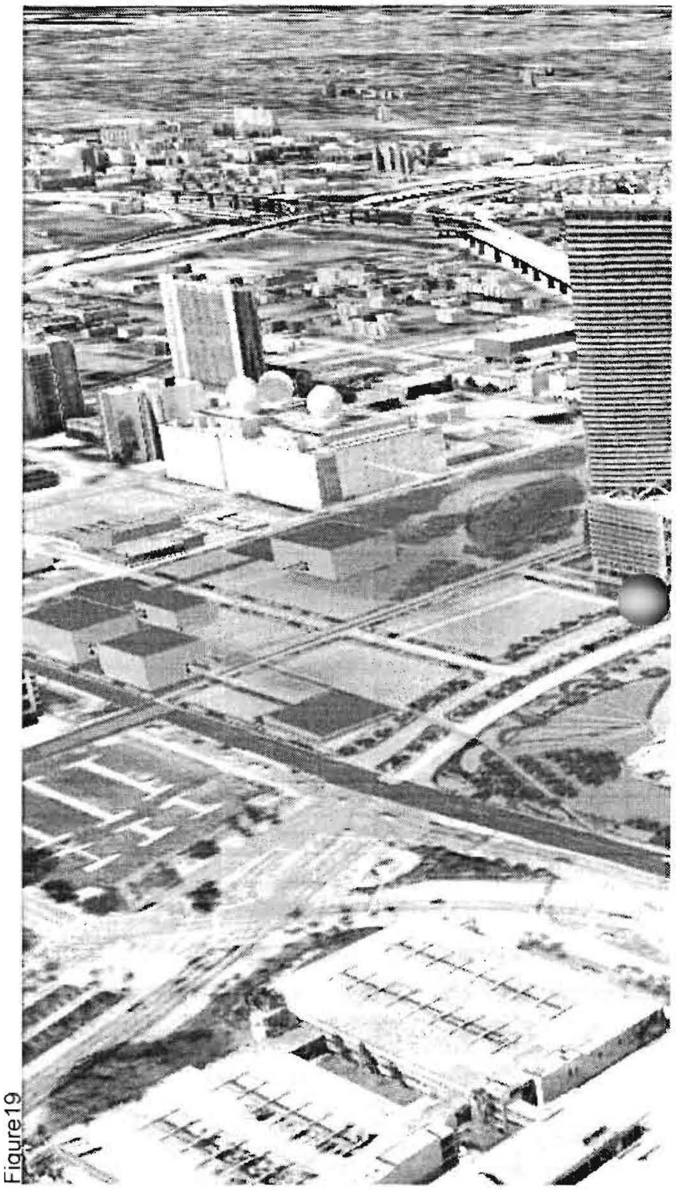
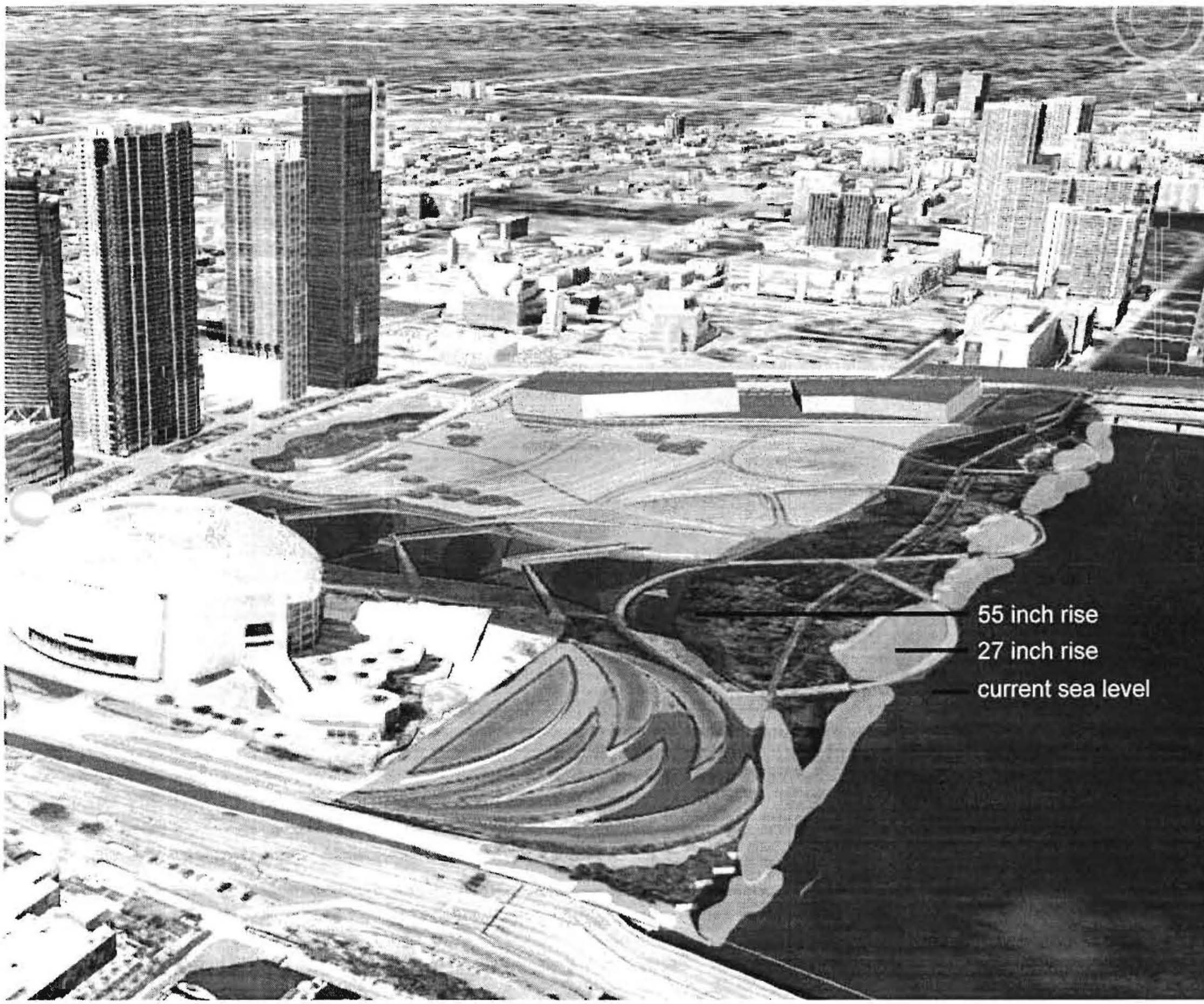
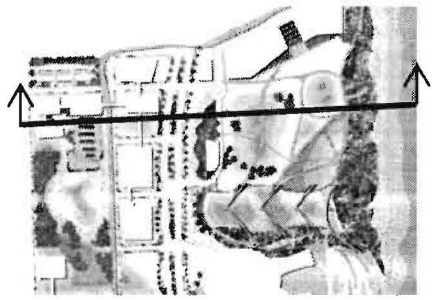


Figure19

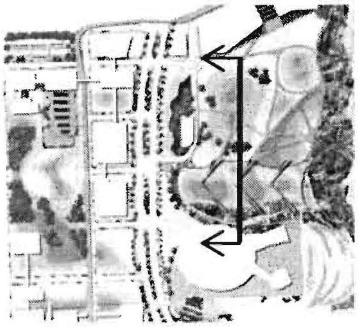
daily
yearly
10-year storm
50-year storm


55 inch rise
27 inch rise
current sea level

[redacted]

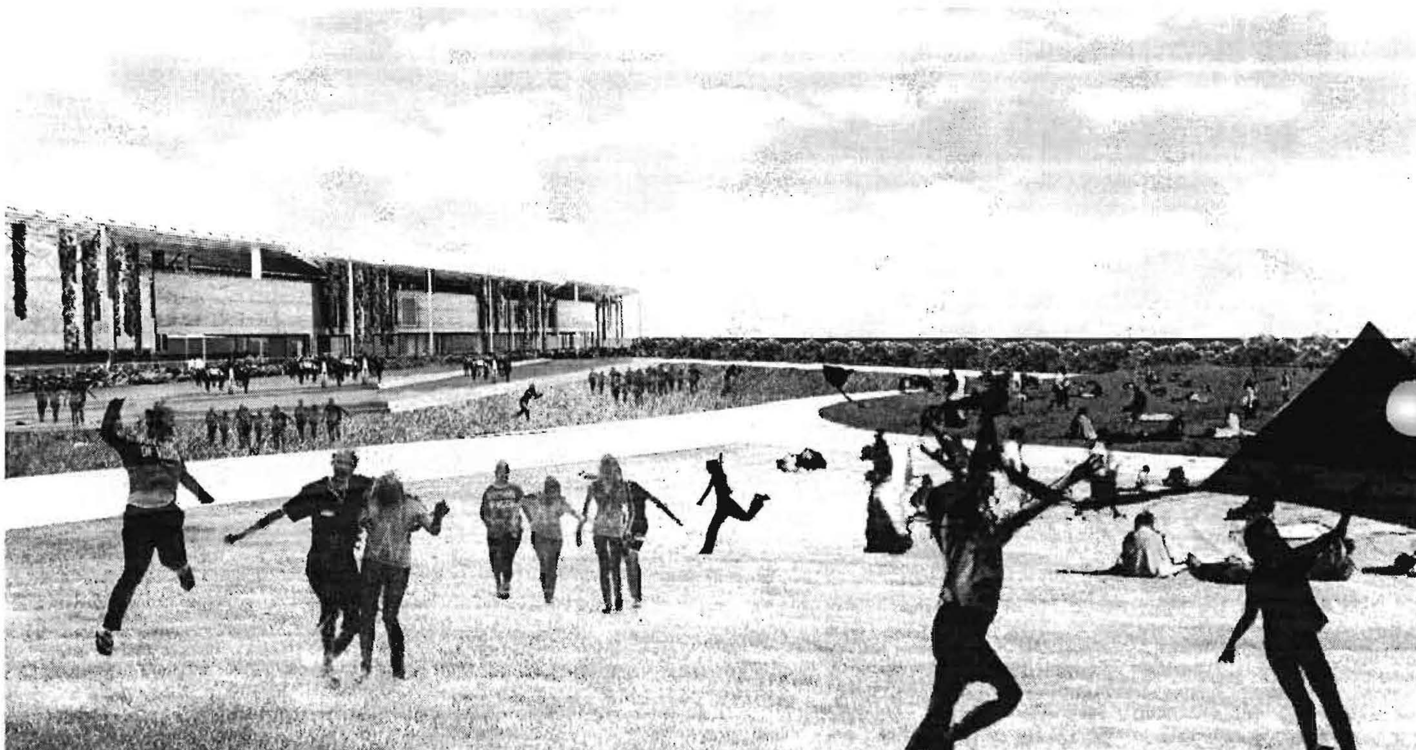


EAST to WEST SITE SECTION



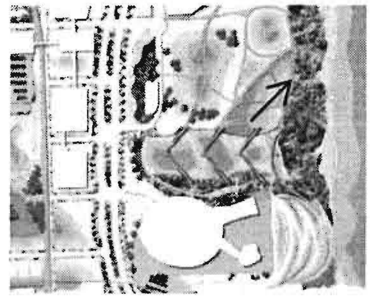
[redacted]

SECTION of CANAL and raised RECREATION



VIEW OF PEDESTRIANS USING OPEN FIELD IN FRONT OF MIAMI ART MUSEUM

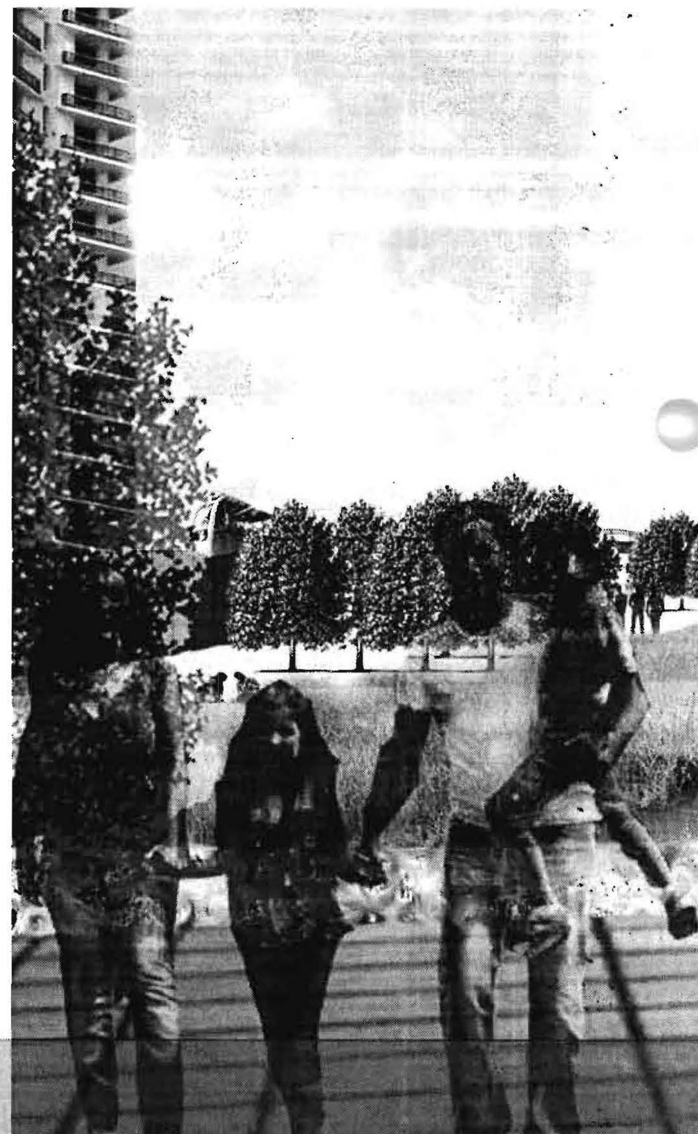
An open area in front of the Museums allowed users to play, relax, gather, or participate in any other activity they want.

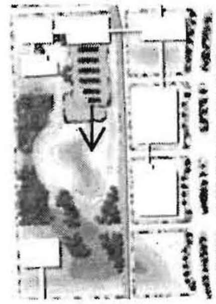


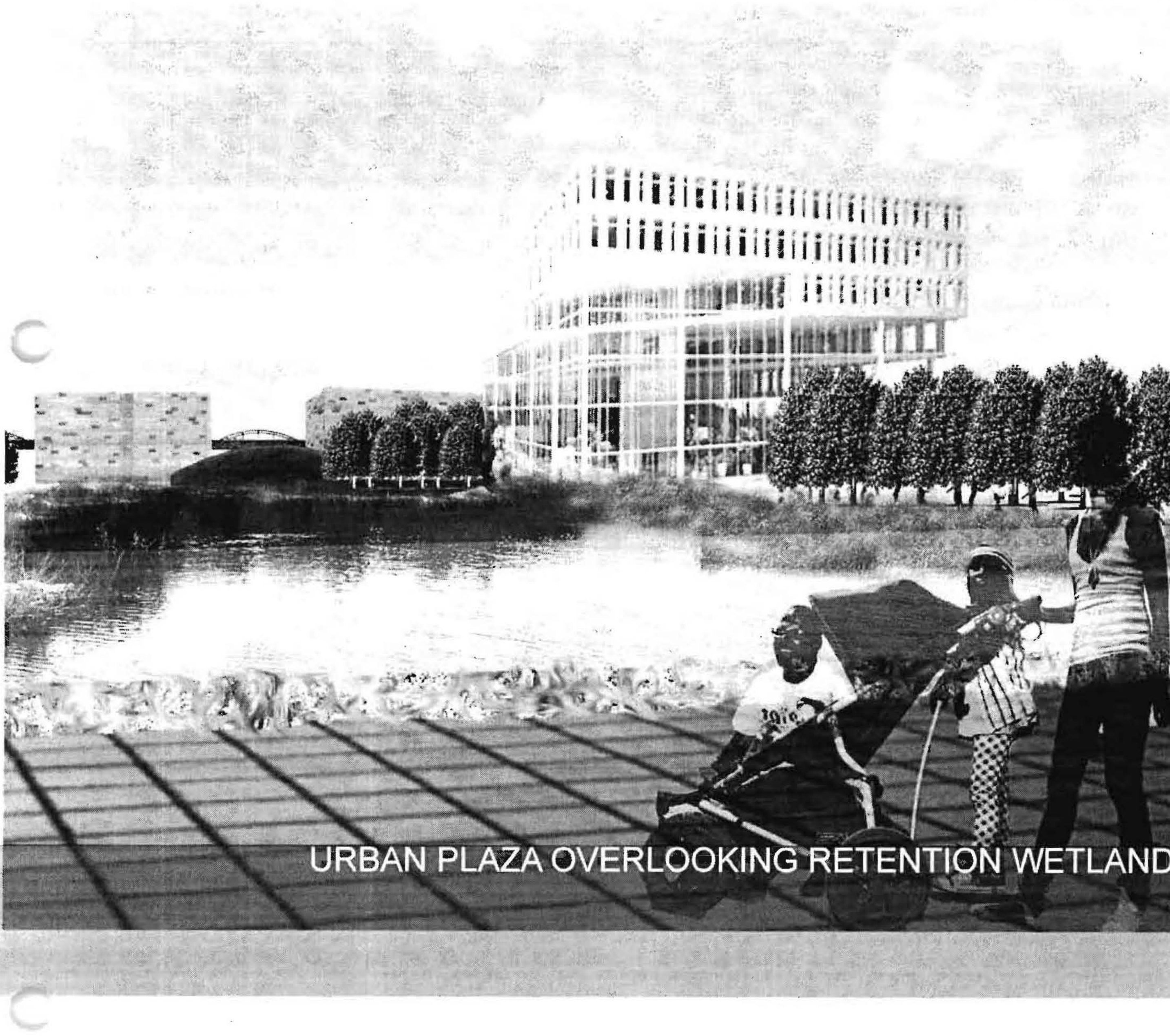
Music festivals and community events would be held at the amphitheater. This area provided the community and visitors a place to celebrate Miami's culture and vibrant music. The steady slope of the four separate viewing areas provided great views of the bay and potential performers while being accessible to everyone. Stormwater was drained to the edges and toward the center where it is filtered before it enters a water retention vessel under the raised areas. The walls supporting the highest ends of the viewing areas were aesthetically pleasing as well as functional. They provided seating and shade from the hot Miami sun.

VIEW OF AMPHITHEATER OVERLOOKING MANGROVES AND BISCAYNE BAY

The urban plaza on the western side of the site provided a great area for community members and visitors to experience an oasis in an urban environment. The vast areas of vegetation allowed for formal and informal recreation. The increased vegetation gave better views for residents living in the high-rise buildings and provided habitat for native wildlife. The retention wetland that the plaza overlooked was able to expand with the pressures of rain events. This gave users access to the retention area no matter the level of water. The retention wetland collected stormwater from surrounding buildings and hard-scapes. This area gave the stormwater time to filter before re-entering ground water resources. With parks on both sides of Biscayne Boulevard, a connection was created across the "Biscayne Wall" that broke up the site before.





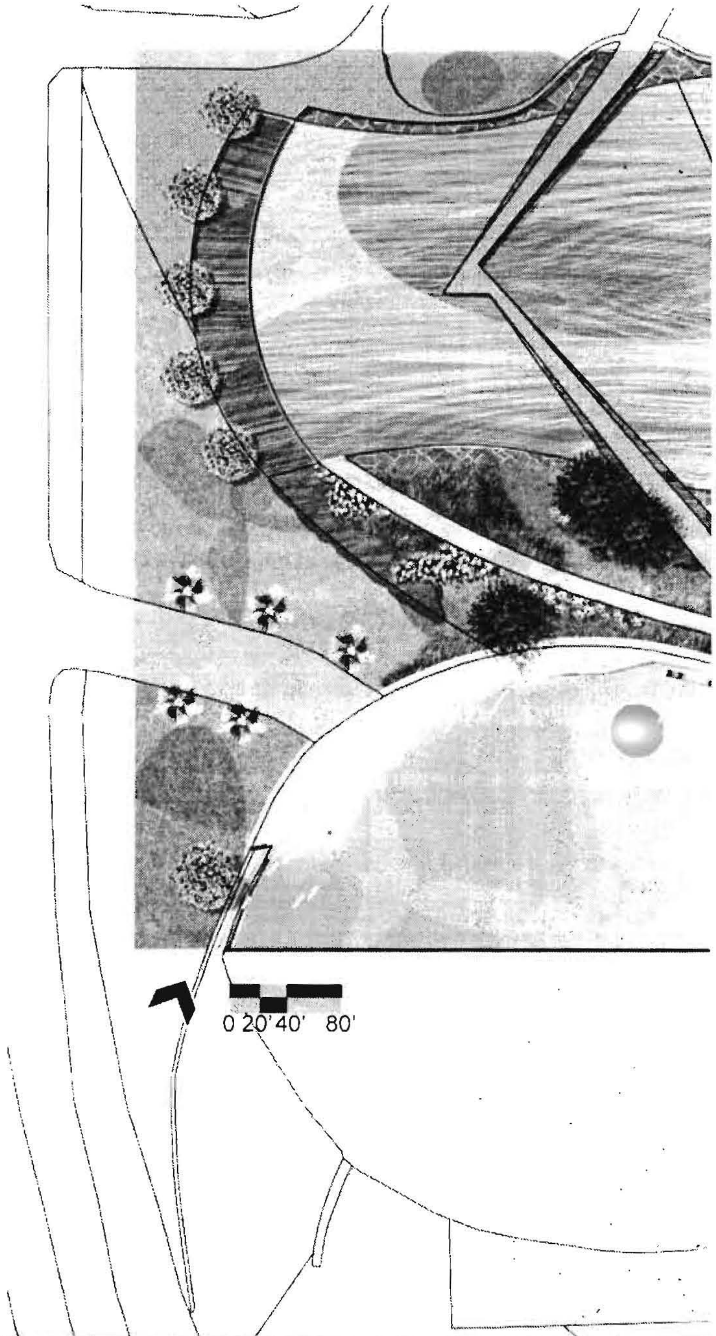


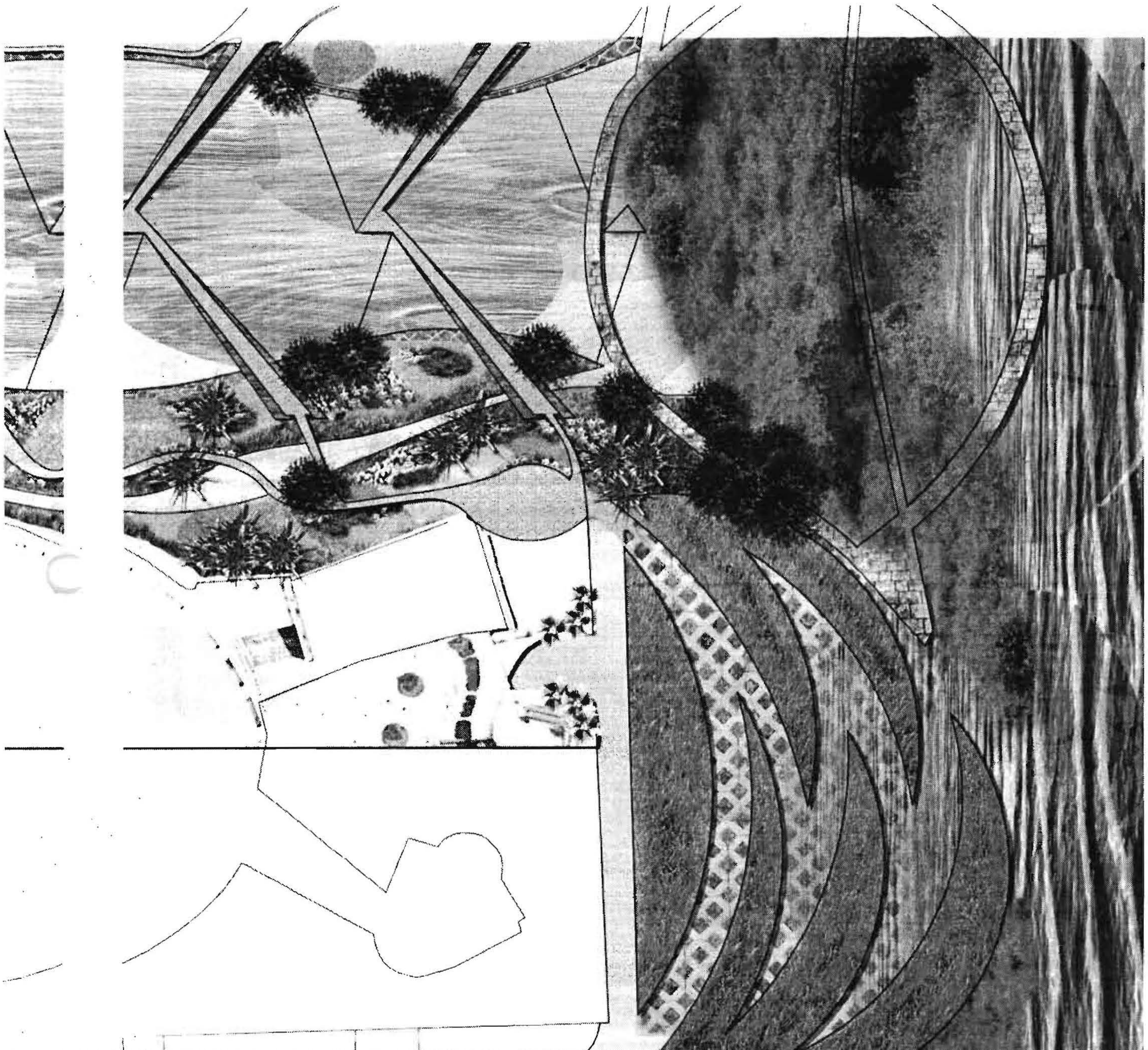
URBAN PLAZA OVERLOOKING RETENTION WETLAND

[redacted]

A closer look at the flood management canal revealed pedestrian bridges over the canal, flood gates, and flood gardens. The pedestrian bridges provided access the canal while giving views of the mangroves and Biscayne Bay. The flood gates controlled the level of each section depending on sea level rise and rain event. If there were to be a long, intense storm, a stream overflowed into the surrounding gardens full of plants that could withstand wet feet. This process of water release helped with cleaning the water before it entered Biscayne Bay.

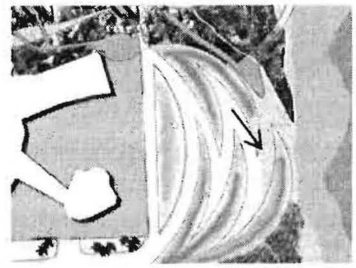
Interaction with the bay was a strong design influence. Pedestrian access was available through a managed access point for kayaks, canoes, and other non-motorized water sports.





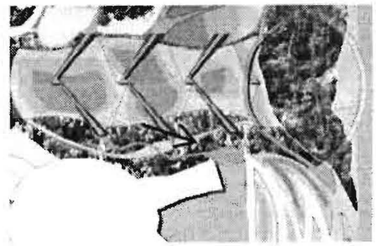
CANAL ZOOM-IN

As mentioned earlier, pedestrian access was an important design program. A spiral rip-rap ramp and kayak launch, which lengthens and shortens according to tidal levels, created easy access between the upland and water's edge. The pavers lining the bottom provided drainage as well as non-slip access. The raised topography protected the upland area from storm surges and sea level rise.

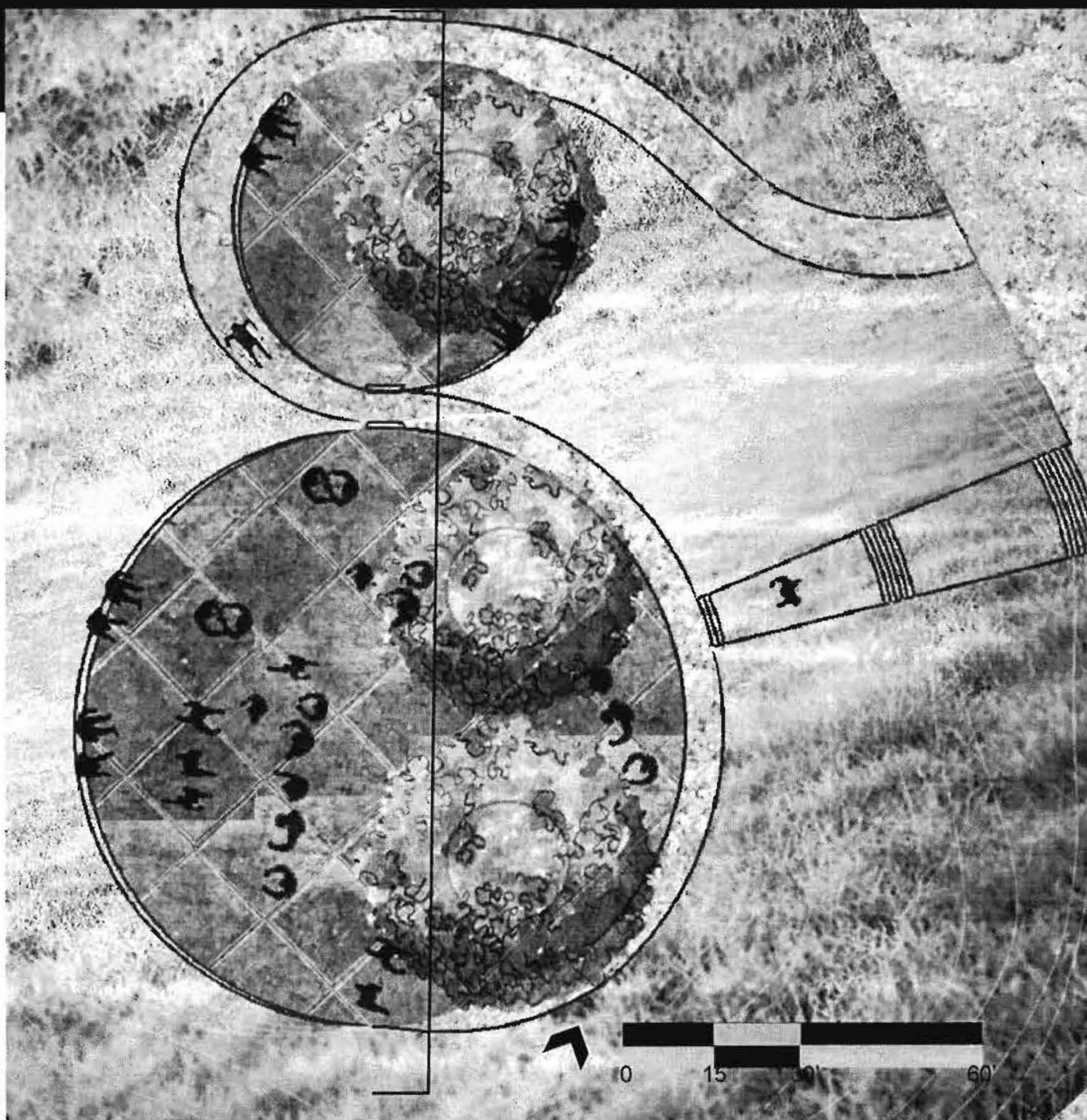


VIEW OF PEDESTRIANS USING THE KAYAK LAUNCH

The flood gardens presented an area that was able to adapt depending on the intensity of sea level rise or storm surge. All vegetation in the garden can withstand high salt intrusion and wet feet. This type of vegetation also cleans the water as it re-enters the ground water resource.

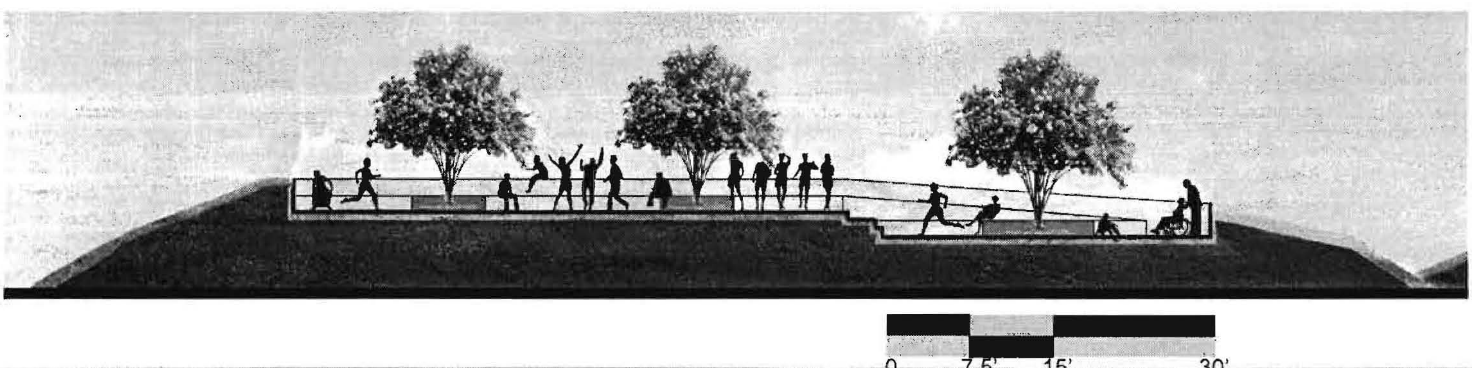


VIEW OF FLOOD GARDENS



OUTDOOR EDUCATION CENTER

The education center offered an area for classes held by the Museums to be outside and immerse students in learning. The education center was able to be accessed by everyone and offered great views of the whole site.



VIEW OF RETAINING WALL AND GREEN SCREEN

Retaining walls throughout the site represented Miami's culture. Vegetative green screens filled with vibrant native vegetation offered aesthetic value, shade, and areas to rest.

All stormwater drained from the raised topography areas to the edges lined with gabion walls. These walls could be used as seats for pedestrians as well as to filter the stormwater. The water is then cycled through aggregate into a retention vessel underneath the raised areas. Here the water was stored until it was needed for irrigation or could be released into Biscayne Bay.

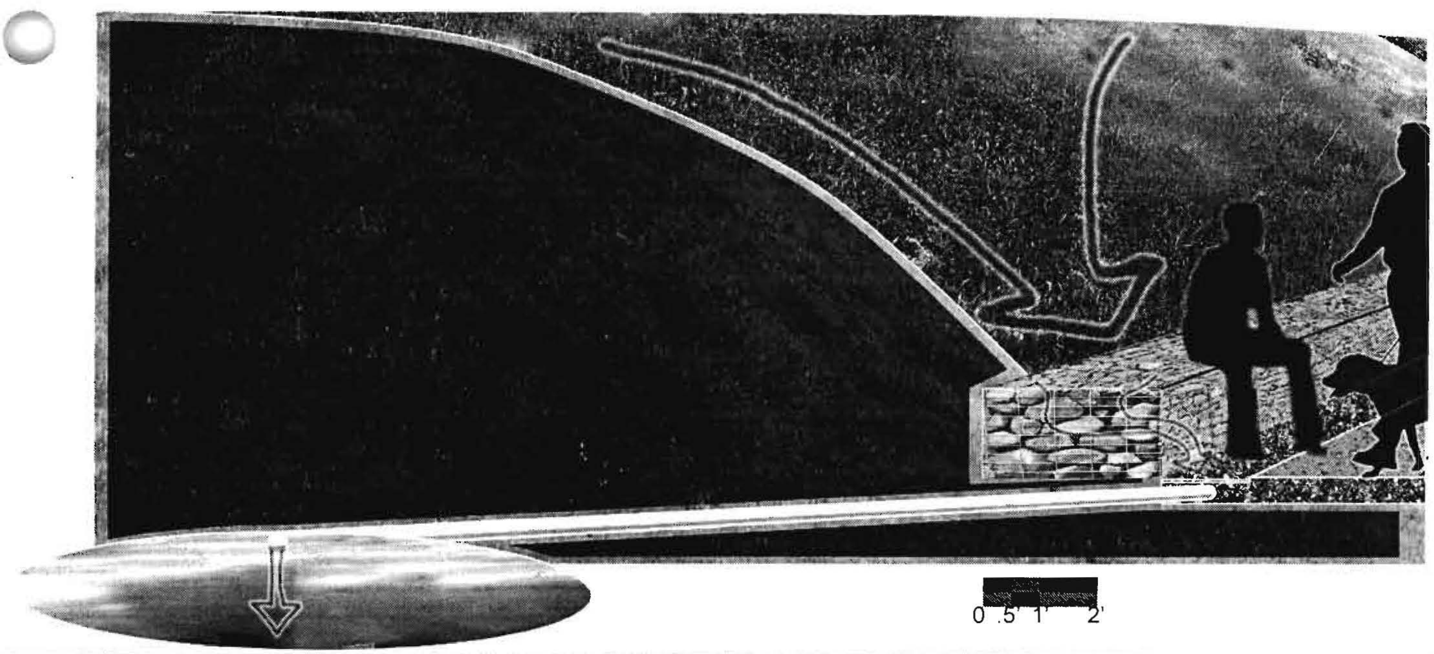
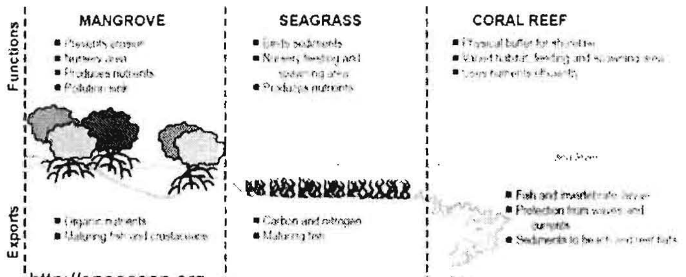


DIAGRAM OF WATER DRAINAGE AND STORAGE



http://oneocean.org

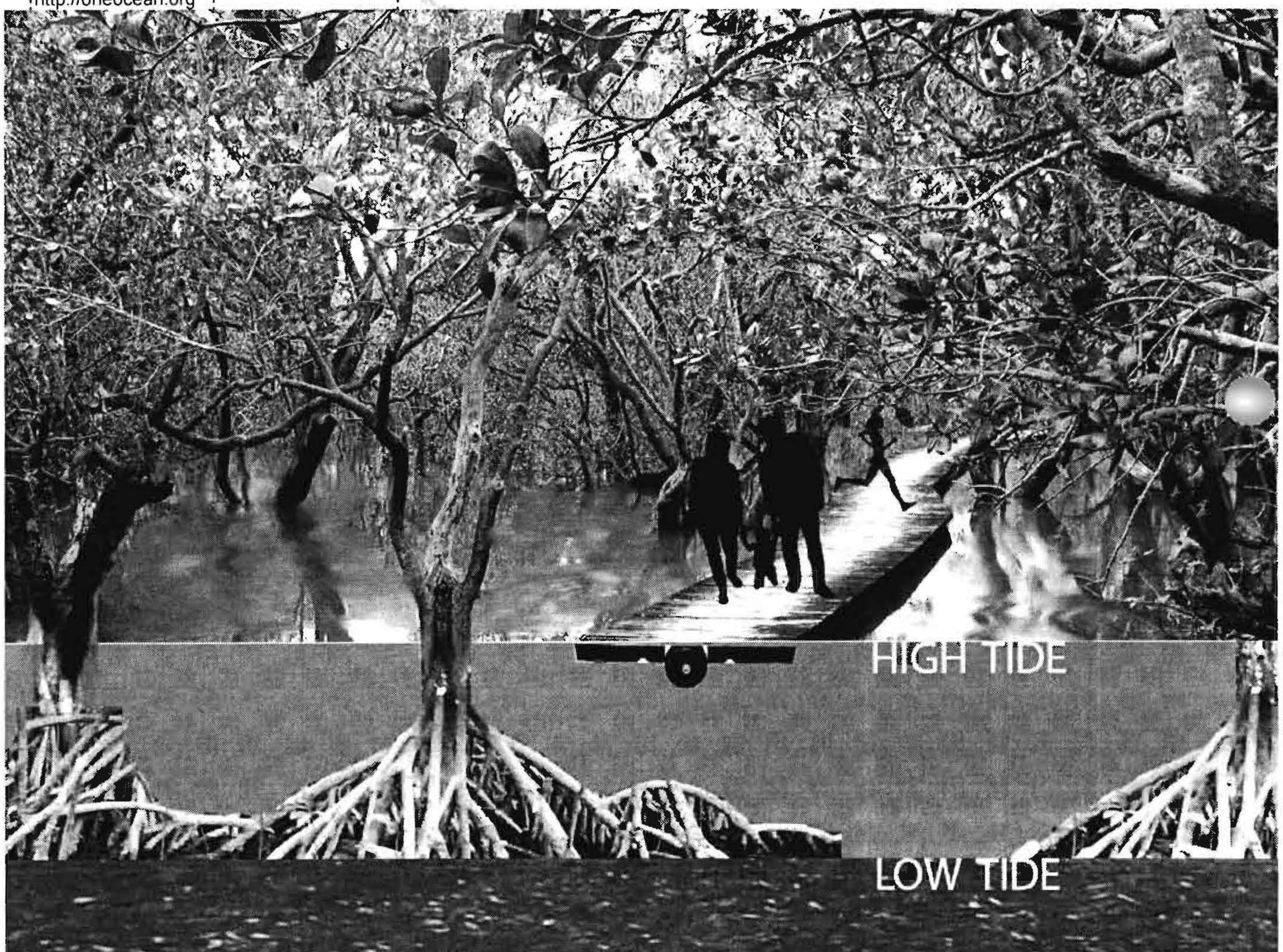
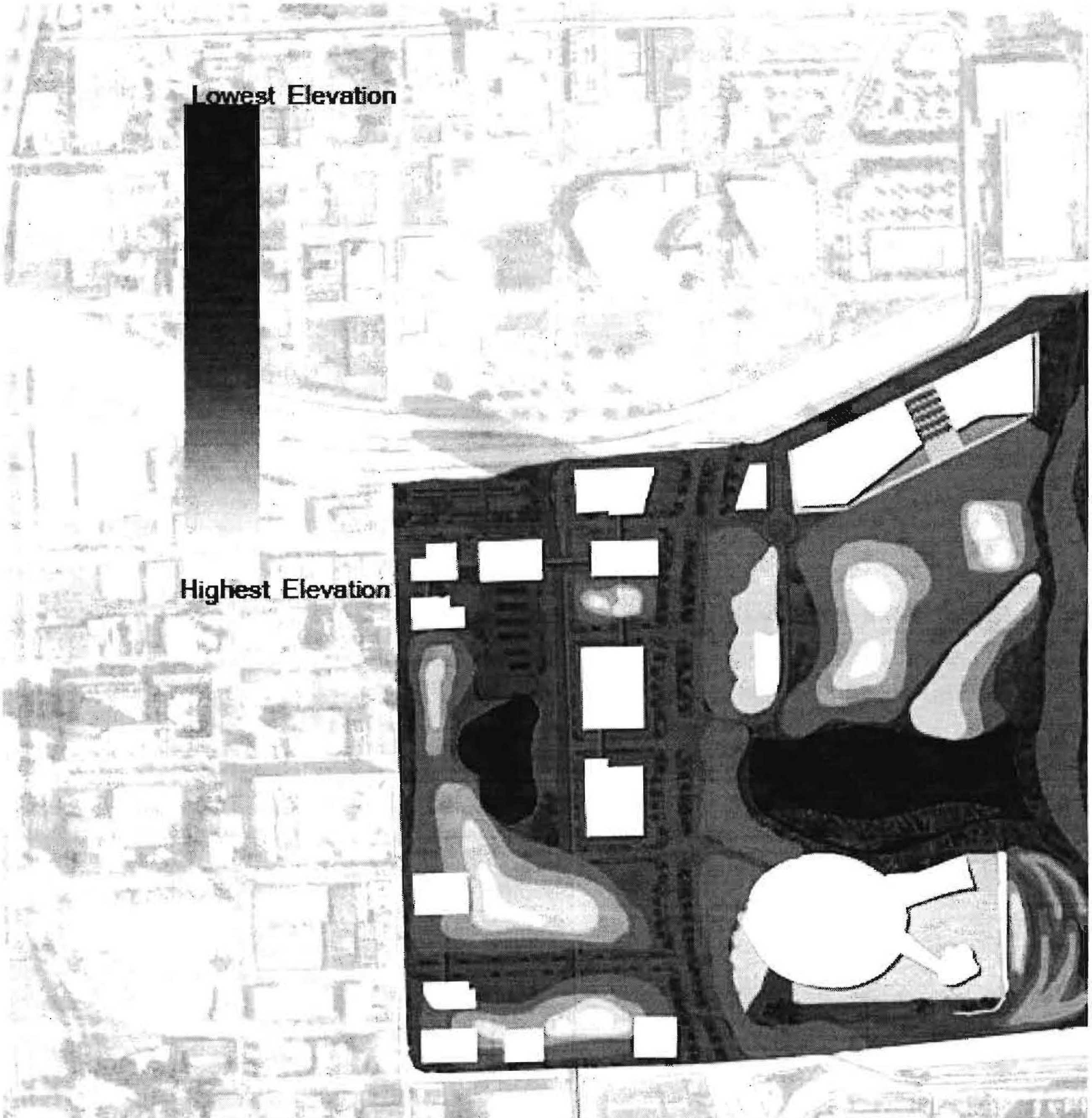


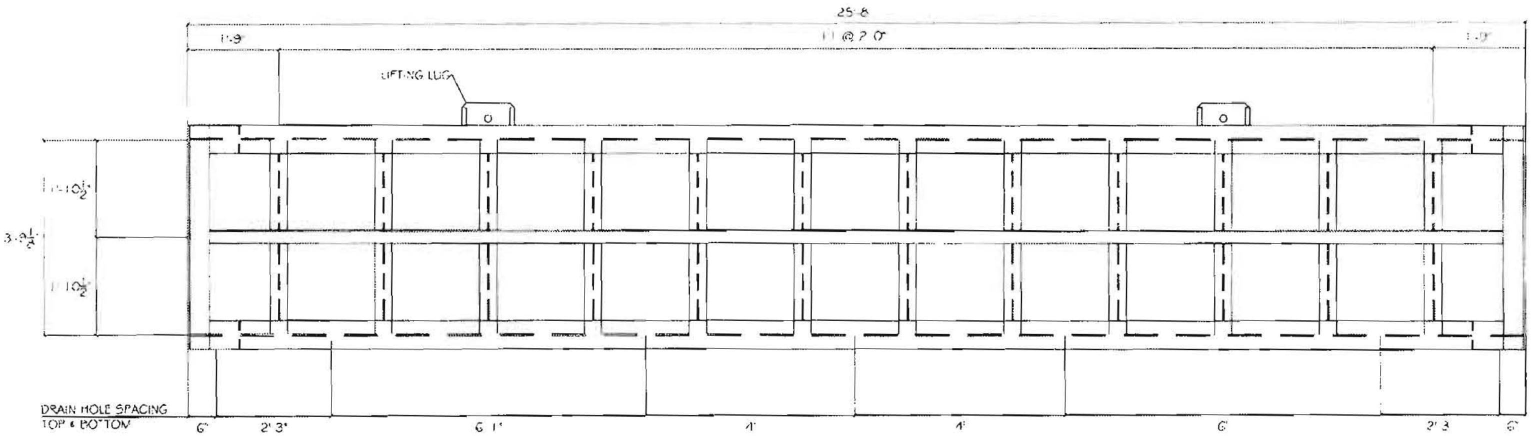
DIAGRAM OF MANGROVES AND FLOATING WALKWAYS

PLAN DETAILS

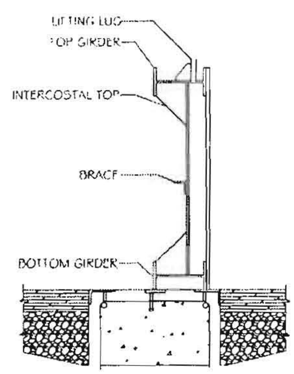
The site was greatly influenced by topography changes. The original appeared almost flat, but now has areas of up to 17' in order to distribute floods around it. When visitors were wandering around the site, views were blocked then re-opened depending on where and what elevation they were at. These changes in topography emphasized the views available throughout the site.

Two types of details were specific to this site. One was the flood gates in the flood management canal. These gates represented the ability to adapt to all unknown threats. The other was the sea wall used in the canal. The curved edge to the sea wall reverted the pressure of the waves back so there was not as much stress on the wall.

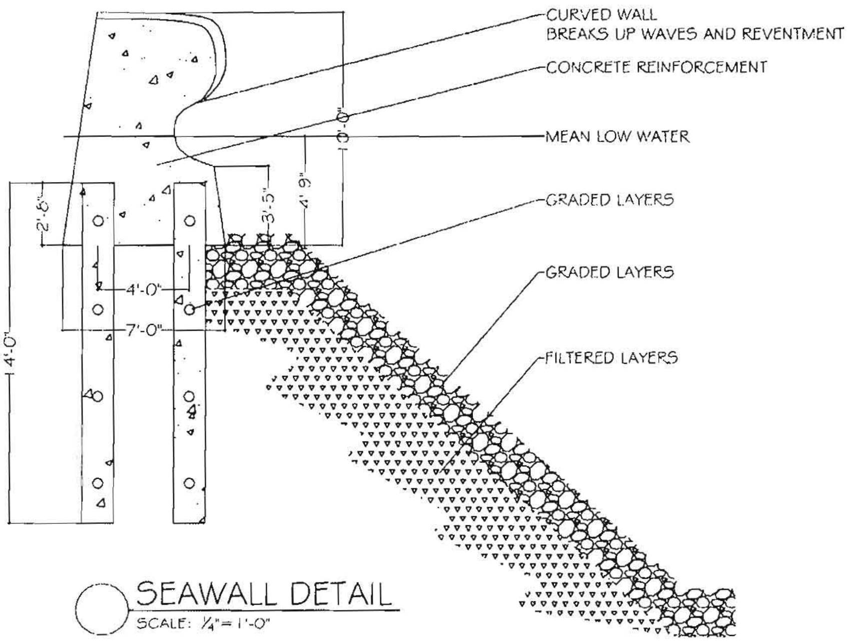

Lowest Elevation
Highest Elevation



SEAWALL ELEVATION
SCALE: 3/4" = 1'-0"



SECTION THRU GATE



SEAWALL DETAIL
SCALE: 1/4"= 1'-0"

SUMMARY

Miami is a vibrant, cultural mega city with great infrastructure and large population. The quality of the bay and surrounding ecosystems suffered due to the lack of attention put on the environment when developing along the coast. This site provided an opportunity for a new way of developing a space through resilient design. After careful analysis of projected threats due to climate change and intense development, it was clear a solution needed to be presented. The introduction of ecological approaches and new technologies would ultimately lead to the protection and restoration of the upland area and aquatic ecosystems. As the design developed, the spaces became more defined for specific purposes of connecting and interacting people with the environment.

The success of the design began with the understanding of the ecology of the site and how restoring the ecological strength of the area would reinforce and protect the infrastructure from unknown threats. The space functioned during dry times and adapted to remain functional during times of high tide or sea level rise. The entire area was open for use as pedestrians saw fit—education, exploration, passive recreation, or relaxation. The new Museum Park had a great location that would draw thousands of people in. Further expansion of the ecological implementation to the West created connections for community residents to the coastline. The park created a new innovative way to approach a sustainable future, demonstrating positive effects of technology mixed with ecological designs.

APPENDIX A

Definitions

BUILT ENVIRONMENT
The term built environment refers to the human-made surroundings that provide the setting for human activity, ranging in scale from personal shelter and buildings to neighborhoods and cities, and include their supporting infrastructure such as water supply and travel and energy networks. This is also what is being referred to when described as 'static' or 'developed.'

CLIMATE CHANGE
According to the Environmental Protection Agency, climate change is a significant and lasting change in the statistical distribution of weather patterns over periods of time. In regards to this research, it is a change in average weather conditions and distribution of events around that average (more extreme weather events).

DISASTER MITIGATION
As defined by the Environmental Protection Agency, disaster mitigation is any action taken to eliminate or minimize the impact of a disaster on people, property and the environment.

ECOLOGICAL DESIGN
As defined by Forster Ndubisi in Ecological Planning, ecological design is the creation of sustainable communities while regarding the relationships and interrelationships within a living landscape.

EXPOSURE
As defined by Donald Watson and Michele Adams in Design for Flooding, exposure is the measure of people, property or other interest that would be subjected to given risk.

HAZARD
As defined by Donald Watson and Michele Adams in Design for Flooding, hazard is the product of risk, vulnerability, exposure, and capacity of humans to respond to extreme events.

MEGACITIES
A megacity is usually defined as a metropolitan area with a total population in excess of 10 million people or minimum level of population density at 2,000 persons/square km while also having a high degree of centrality within the national economy. Miami is a megacity.

NATURAL SYSTEMS
Natural systems are biophysical systems that have had relatively little influence from human socio-cultural systems and have minimal dependence on mechanical elements. Because these systems naturally change, this is what is being referred to when described as 'dynamic' or 'shifting.'

RISK
As defined by Donald Watson and Michele Adams in Design for Flooding, risk is the probability of an event or condition occurring.

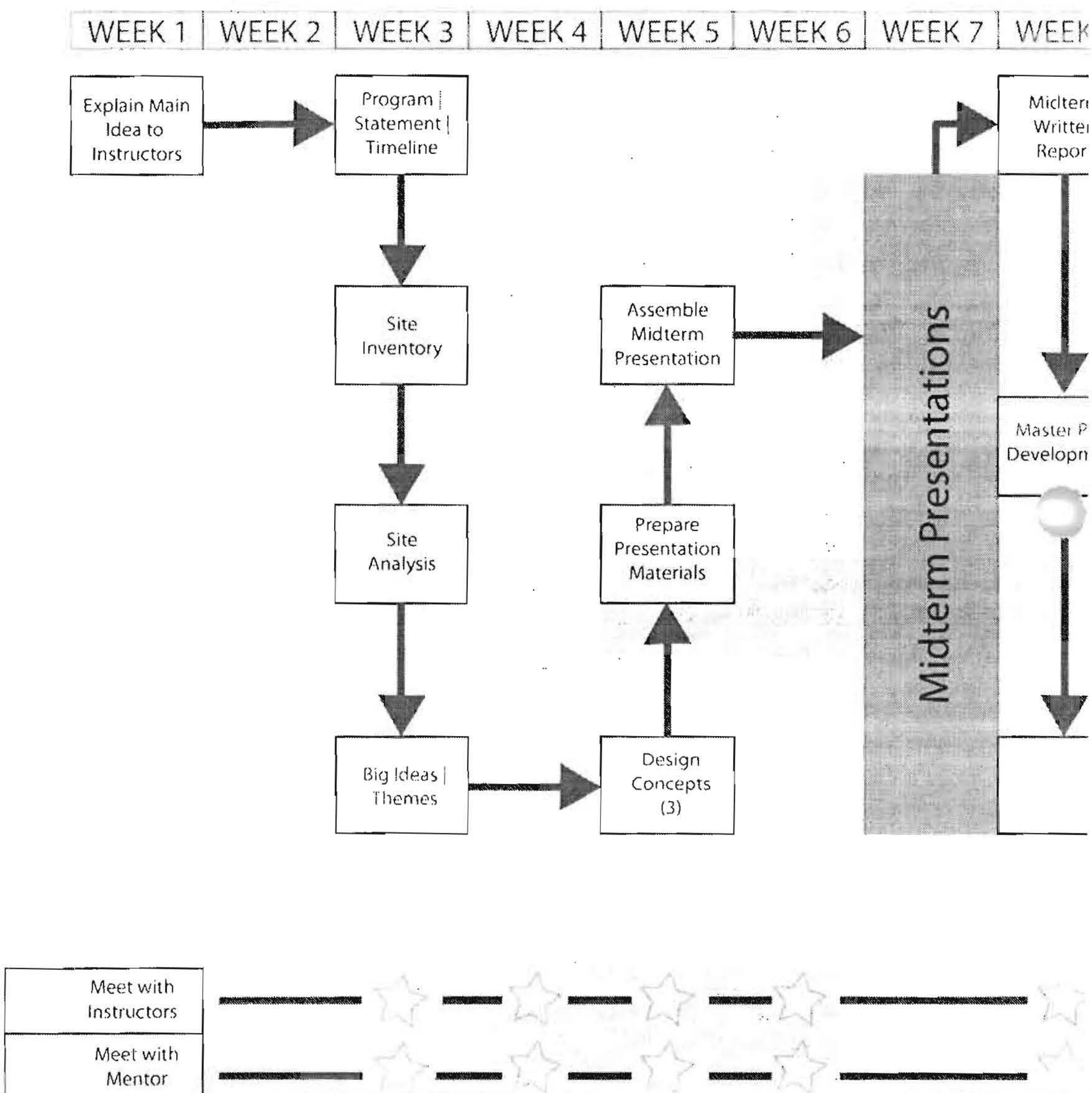
SUSTAINABILITY
As defined by the Brundtland Commission, sustainability is defined as development that "meets the needs of the present without compromising the ability of the future generations to meet their own needs." In regards to this research, this will be achieved through designs that choose to preserve natural landscapes and improve natural systems.

URBAN ENVIRONMENT
An urban area is characterized by higher population density and vast human features in comparison to areas surrounding it. Because of its high density and complex and high amount of supporting infrastructure, Miami is considered urban context.

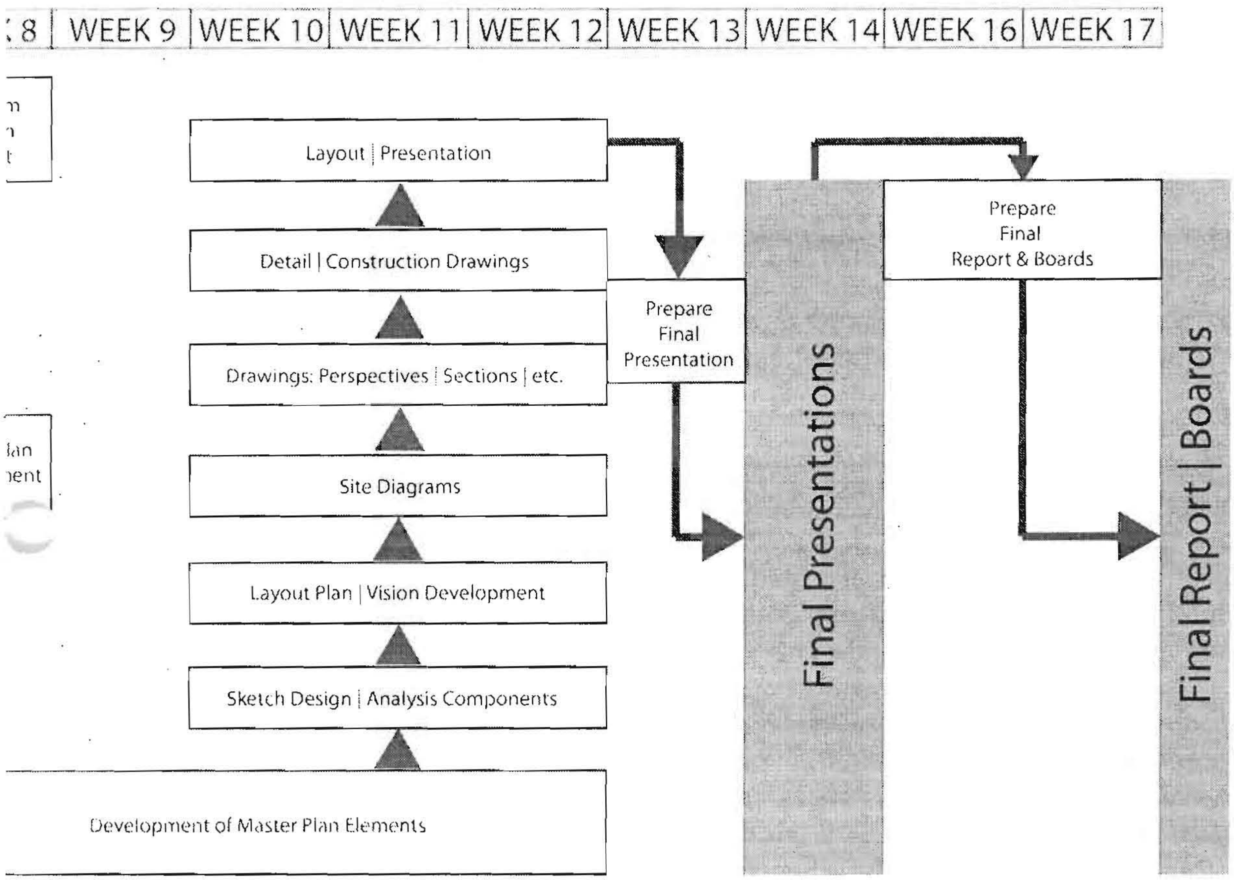
VULNERABILITY
As defined by Donald Watson and Michele Adams in Design for Flooding, vulnerability is the measure of capacity to resist or recover from impacts of a hazard in long term as well as the short term.

APPENDIX B

TIMELINE S



CHEDULE



Design Development, Master Planning, Supporting Graphics & Refinement

Final Report | Boards

APPENDIX B

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